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BLINDNESS OR BLAST OF OATS

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"Blindness" or "Blast" of oats, in which a proportion of the spikelets are white and undeveloped at the time of emergence of the panicle, and remain sterile, is of very common occurrence. It varies in amount in different seasons and often appears to affect the yield of grain seriously.

Von Seelhorst (*9*) in a study on the influence of water-content on plant development, showed that dry weather before and during the time of emergence of the panicles increases the number of blind spikelets. He found that the total number of spikelets formed was affected by the water-content during the early vegetative period, high moisture being correlated with high spikelet number. Low moisture at the time of panicle emergence caused many spikelets to remain undeveloped and "blind". More "blind" spikelets were found on plants that were kept moist during the early stages of growth and then subjected to drought than on plants which were kept too dry throughout, though the percentage was lower in the former owing to the much larger total number of spikelets formed. The smallest *number* of blind spikelets occurred in plants which were dry at first and then plentifully supplied with water during the period of panicle emergence, and the smallest *percentage* of blind spikelets and the largest total *number* of spikelets were found on plants that were kept moist throughout.

These results were confirmed with both field and pot cultures by Bunger in 1908, according to Zade (*10*) who further cites a very large number of insect pests and fungal and bacterial diseases which may cause blast either of the whole panicle or of a number of the spikelets.

Manns (*7*) in a bulletin on the bacterial blade blight of oats stated that the amount of blast observed was more or less proportional to the extent of the blight, and that blast may be due either to direct killing of the parts or to reduced vitality of the plant caused by the blight some time before the panicles emerge.

Hewitt (*5*) observed that in Canada sterility of the lower spikelets of oat panicles was commonly caused by thrips, and Roebuck (*8*) noted that in England blast is associated with attack by the frit fly, *Oscinis frit*. Two main attacks on oats by the frit fly are commonly recognized: an early one which destroys the young tillers and a late one in which the developing grains are destroyed. Roebuck is of the opinion that an intermediate attack occurs and manifests itself as blast. He noted that while all varieties under his observation were affected by blast, they varied considerably in the proportion of their *panicles* that were affected.

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Elliott (*2*) states that her attention was first drawn to blast by the observation that plants showing much spikelet sterility occurred in fields considerably infected with halo blight. She tested this possible relationship and found that spraying plants at about the time of panicle emergence with a water suspension of the halo blight organism produced a great increase in the number of sterile spikelets, but that spraying with sterile water had a similar effect. The opinion was advanced that rains falling about the time of emergence of the panicle probably caused much blast. Miss Elliott also noted that different varieties apparently varied in their percentage of blast. As a result of further study (*3*) she showed that great seasonal variations in the amount of blast occur, but that the proportional differences between varieties remain fairly constant. Contrary to her expectation from the spraying experiment, she found that the greatest amount of blast occurred when the weather was abnormally dry at the time of heading. She noted that the varieties showing the highest percentages of blindness were of known or suspected hybrid origin, and thought that this might have some bearing on the origin of the sterility.

The present author's attention was drawn to this problem in 1924 when he was in the Department of Field Crops of the University of Alberta and was growing wild oats, Banner oats and false wild oats (from Banner) in adjacent plots. These three sorts of oats were sown at approximately ten day intervals from May 2 to July 15, 1924. It was observed that there was much blindness in the false wild oats, and very little in the wild oats, and that Banner oats seemed to have somewhat less than the false wild. At the same time it was noted that the average total number of spikelets per panicle was clearly smaller in the wild oats than in the other two sorts. The percentage of blindness was enormously greater in the later sowings but the increase did not seem to be quite proportional in the three sorts. It seemed that this might be favourable material for biometric study. The possible relation of number of blind spikelets to total number of spikelets had not been closely studied by any of the earlier workers cited above, and by working with two strains very similar and one widely dissimilar it was hoped that it might be possible to get some indication of how far the differences were due to specific resistance and how far to general physiological causes. Earlier studies which have shown merely the percentage sterility in different varieties without reference to the total number of spikelets per head or the variation within each variety, do not throw any light on possible physiological differences.

If a significant correlation were found between high total spikelet number and high percentage of blindness, under uniform conditions of growth, then it might be reasonable to assume that blindness is in part due to physiological inability to develop all the spikelets formed and that the commonly noted loss in yield due to blindness is therefore more apparent than real. On the other hand, if no correlation were found it would indicate that selection or breeding of resistant varieties is feasible. On this score it must be mentioned that there appears to the writer to be no basis for Miss Elliott's suggestion that blindness may possibly be connected with hybridity. Apart from the fact that all varieties of *Avena*

sativa and *A. fatua* are practically certainly of ultimate hybrid origin, any sterility due to hybridity would not ordinarily be expected to manifest itself until the time of flowering, which is considerably later than the stages when blindness first appears. Blind spikelets can be detected at an early stage of development considerably before panicle emergence. At the time of panicle emergence they are white and shrivelled. The sterility of hybrids obtained by species crosses is certainly very different from that of oats affected by blast. There appears therefore to be no *a priori* case against the possibility of breeding good resistant varieties if factors for resistance to blindness exist in any strains of oats. Owing to the pressure of other work this biometric study had to be laid aside before any conclusions had been reached, and only recently has it been possible to conclude it.

Material and Methods

Three lines of oats selected and grown for a number of years in the Department of Field Crops of the University of Alberta, and known to breed true, furnished the material for this study. They were: 1, a common type of brown-seeded wild oats, *A. fatua* L.; 2, a strain of homozygous false wild oats selected from *A. sativa* L. var. Banner; and 3, pure "Elite" Banner oats. These three sorts were sown in adjacent plots of 128 seeds each on May 2, May 12, May 23, June 6, June 16, June 25, and July 15, 1924. For the statistical study 50 panicles were taken on September 11th from each plot of the first five sowings, not more than one panicle being taken from any one plant, and the selection of both plants and panicles being at random. The last two sowings were so badly developed that they were useless for this study. This random selection of panicles introduced very great variation into the samples. It now seems that it would probably have been better to select only the plants at random, and to take the primary panicle from each of these plants.

Supplemental to this principal material, 50 panicles each were taken from departmental plots of *A. strigosa, A. brevis, A. abyssinica, A. byzantina, A. nuda,* and *A. sativa* var. Victory, which were growing in a different field.

Statistical Analysis

The total number of spikelets in each lot of 50 panicles and the total number of sterile spikelets are set out in table 1.

Table 1.

Date of Sowing	Wild Oats		False Wild Oats		Banner	
	Total No. of spikelets	No. of sterile spikelets	Total spikelets	Sterile spikelets	Total spikelets	Sterile spikelets
2–5–24	1938	24	2146	404	2233	480
12–5–24	1967	57	2475	435	2741	483
23–5–24	1926	81	2090	446	2224	369
6–6–24	2310	202	1909	438	2050	348
16–6–24	3381	587	2546	1113	3171	1417

Pearson and Elderton's χ^2 test for independence (Fisher) was applied to these data to determine the significance of the differences in proportion of sterility between wild oats and Banner, and false wild oats and Banner, respectively. Between the former two this test gives in each case a large value for χ^2 and the chances are in no instance less than 1000 to 1 in favour of the differences being significant and not merely errors of sampling. Between the false wild and Banner oats of the first sowing $\chi^2 = 3.22$, and P, read from Fisher's Table III (1925, "Table of χ^2") $= .10$; for the second date $P = .98$; for the third and fourth it is .01; and for the fifth, .60. The difference between the two sorts in the first sowing is therefore no greater than would be expected to occur ten times in one hundred through chance sampling, and there are clearly no significant differences in the proportions between the two sorts in the second and fifth sowings. For the third and fourth sowings the proportion of sterile spikelets seems possibly to be significantly greater in the false wild oats, since such differences would each be expected to occur through errors of sampling only once in one hundred times. The wild oats are therefore clearly less liable to blindness than either false wild oats or Banner, and the false wild are *probably* more susceptible than Banner under some conditions of growth.

The size of panicle and proportion of sterility varied very greatly within each of the collections of 50 panicles, and simple calculations of the percentage sterility without consideration of the degree of variability were therefore of very little value. The percentage sterility, with its probable error which indicates the comparative variability, was calculated for each sample of the first four sowings, with the results shown in table 2.

TABLE 2.

Date of Sowing	Percentage Sterility		
	Wild Oats	False Wild Oats	Banner
2–5–24	1.13 ± .20	20.36 ± 1.28	23.67 ± 1.34
12–5–24	3.26 ± .37	17.91 ± .83	16.95 ± .92
23–5–24	4.49 ± .59	22.22 ± .91	16.80 ± .66
6–6–24	9.78 ± 1.72	22.05 ± 1.43	17.35 ± .67

These results further demonstrate the clearly significant difference in proportional sterility between wild oats and either false wild or Banner. They emphasize also the interesting differences between Banner and this strain of false wild oats from it. As mentioned, it was noticed in the field that the false wild seemed to have many more blind spikelets than the Banner, and as we have seen, the χ^2 test indicated that the differences were almost certainly significant in the third and fourth sowings, but clearly not in the first, second or fifth. For the first sowing, table 2 shows Banner to be more affected by blast than the false wild by 3.31 per cent, but the probable error of this difference is 1.82 and the difference is therefore of doubtful significance. In the second sowing the false wild have 0.96 per cent more

blind spikelets than the Banner, but as the probable error of this difference is 1.22, it is clearly not significant. In the third and fourth sowings the differences are 5.42 ± 1.13, and 4.70 ± 1.58 respectively, and as in one case the difference is nearly five times as great as its probable error, and in the other practically three times as great, these differences can probably be considered significant. The probable error test which takes into consideration the variations of the individual plants, and involves somewhat laborious calculations, therefore confirms the indications given by the easily applied χ^2 test which dealt only with the gross totals.

The problem of whether low proportions of sterility are associated with low total number of spikelets was studied first by means of correlation tests and various forms of graphical analysis. These tests indicated that there was no significant correlation, but the results were not nearly so definite as those obtained recently by the application of Fisher's (1930) method of "Intra-class correlation as an analysis of variance". The earlier tests are therefore omitted and only the latter test, of which the results are embodied in table 3, is presented.

Fisher's method gives a statistical separation of the differences due to variety and not concerned with panicle size from those associated only with panicle size. The data from the first four dates of sowing only were used. The different panicles of each of the three strains were grouped into sixteen classes, according to number of spikelets per panicle, with a class-interval of five. Correlations were then obtained, according to Fisher's method, between the number of blind and the number of fertile spikelets both within corresponding panicle-size classes of the three strains compared two at a time and between the different size classes of each strain.

The results given in table 3 are interpreted as follows. In Banner compared with false wild, panicle-size is responsible for three times as much (28.56:9.83) variability in degree of blindness as is variety. In these two strains genetically similar except for the false wild genes, it therefore seems probable that physiological causes associated with the number of spikelets per panicle are responsible for most of the differences in degree of blindness. On the other hand, in the comparison between the genetically very different Banner and *A. fatua*, varietal factors other than those associated with panicle size are responsible for six times (119.78: 20.76) as much difference in degree of blindness as are factors, presumably physiological, associated with panicle size.

It should be mentioned that the early sowings of oats, which showed low proportions of blast, came into head during an unusually dry period of weather which obtained from the middle of June to the middle of July, while the later sowings which showed high proportions of blast came into head during the subsequent wet period. But since each sample collected comprises heads selected at random from plants which were widely spaced and consequently had many tillers, the heads of each sample probably differed considerably in their date of heading, and it is therefore not possible to determine any definite measure of correlation between the degree of blast and the weather conditions. For this reason it has not been thought worth while

TABLE 3.

	$(a - b)^2$	Sum of Squares	Degrees of Freedom	Mean Square $\left(\frac{\text{sum of squares}}{\text{degrees of freedom}}\right)$	S. D.	Nat. Log S. D.	Z	P.
BANNER compared with A. FATUA	$\frac{3114.17}{2}$ $= 1557.08$	Within (Panicle size) = 1557.080 Between (Classes) = 249.103 Total = 1806.183	13 12	119.780 20.758	10.940 4.558	2.3924 1.5153	.8771	More than twice 5% value ∴ significant
BANNER compared with FALSE WILD	$\frac{275.270}{2}$ $= 137.635$	Within (Panicle size) = 137.635 Between (Classes) = 371.368 Total = 509.003	14 13	9.835 28.567	3.136 5.334	1.1429 1.6760	.5330	Nearly twice 5% value ∴ significant

to publish precipitation data for the growth period, though such were very kindly supplied by Professor J. R. Fryer.

The total number of spikelets and the number and crude percentage of sterile ones in each of the samples of 50 panicles from the miscellaneous species of *Avena* are given in table 4. As these grew in a different field from the main material of this study, and were from plants sown at a different spacing, they cannot be compared directly with it. It is however of interest to note the differences between them.

Table 4.

	A. strigosa	*A. brevis*	*A. abyssinica*	*A. byzantina* var. Red Algerian	*A. nuda*	*A. sativa* var. Victory
Total number of spikelets	1921	1628	1771	999	1716	1476
Number of sterile spikelets	385	193	242	53	456	257
Percentage sterile	20.04	11.86	13.66	5.3	26.57	29.52

Discussion

It is obvious from the literature here reviewed that many causes may operate to bring about blindness or blast in oats. The chief object of the present study was, however, to determine, if possible, whether specific genetic resistance to blast exists, apart from precise consideration of the causes. If so, it would indicate the advisability of testing varieties for such resistance and the practicability of initiating selection or breeding work for the production of resistant varieties. On the other hand, if, in the different strains studied, the important correlation were found to be between degree of blindness and panicle size, it would indicate a physiological association and suggest that efforts to breed or select oats for resistance to blindness would be more or less useless. Both Elliott and Roebuck have shown that less blast occurs in some varieties than in others, but they give only the percentage differences in their comparisons of varieties and their data, therefore, do not show whether the proportion of blindness is independent of panicle size or not. The present study clearly indicates that resistance to blast may be combined with high spikelet number per panicle.

Consideration of yield per unit area was not possible with this material, but spikelet number has been shown by Love and Leighty (*6*) to be the most important factor in yield per plant and is undoubtedly a big factor in the yield per acre.

The figures given in table 4 show that blast occurs in many very different species of oats representing all three of the principal subdivisions of the cereal section of the genus. *A strigosa* and *A. brevis* are diploid species with 14 chromosomes, *A. abyssinica* is a tetraploid with 28, and the other three, as well as the three sorts principally studied, are hexaploids. All the tetraploid and hexaploid species are practically certainly of ultimate

hybrid origin. The diploids have more chance of being non-hybrid. There is at any rate no indication, from this study, of hybridity, either varietal or specific, having anything to do with blast, and therefore no *a priori* objection to breeding experiments designed for the production of blast-resistant varieties of oats.

As mentioned, no close correlation of rainfall with time of panicle emergence can be made with these data, but from his general observations the writer agrees with Miss Elliott that rainfall just before the time of panicle emergence probably causes much blast. In view of the multiplicity of causes, her later observation that most blast occurred during a very dry period, does not invalidate her former conclusion based on experimental spraying.

While a detailed discussion of the various causes of blast is not here intended, it may be mentioned with reference to Roebuck's opinion that the frit fly causes much blast, that this strain of *A. fatua* which was so resistant to blast in Alberta has since been found to be resistant to frit fly attack in England. And, further, two segregates from a cross of it with Banner also appear to be significantly more resistant to frit fly than the Banner parent. They have not yet been studied closely in relation to blast.

The correlation between frit-fly attack and blindness, reported by Roebuck, has been confirmed by the writer to a certain limited extent. Panicles which have been attacked in the sheath by frit fly frequently emerge with the whole or a large part of their spikelets blind. The condition in which spikelets scattered over the head are blind does not, however, seem to be attributable to the frit fly. The bearing, if any, of these observations made in England upon the data collected in Alberta, is difficult to determine. The frit fly has not so far been a pest in Canada as in Europe. I am indebted to Professor E. H. Strickland, Department of Entomology, University of Alberta, for the information that the Alberta native species of *Oscinis* breed in the native grasses and not on cultivated grains. Mr. Norman Criddle, Director of the Entomological Laboratory, Treesbank, Manitoba, kindly informs me that while *Oscinella frit* has been introduced and it and other species of *Oscinis* do some damage to seedling wheat and oats in some parts of Canada, they have not been reported as affecting the heads. It would seem worth while to make a further study of the possible relationship between various *Oscinis* species and blindness of oats in Canada. If none is found, then it would appear that in this strain of *A. fatua* we are dealing with correlated resistance to different pests.[3]

It is not, of course, suggested that it is particularly desirable to use *A. fatua* in breeding work for blast resistance. It was used for this study as it seemed favourable material for testing a general principle. It may well be that good varieties or strains of *A. sativa* will be found to be equally resistant to blast and if so, they should of course be used. But if

[3] Since the above was written, Cunliffe (*1*) has presented carefully analysed data which he shows suggest that there is little if any correlation between degree of frit fly attack and either blindness or weather conditions. His data indicate varietal differences, but he notes that the correlation is not high, showing that other factors are involved. *A. fatua* in his experiments suffered heavily from both frit and blindness. A correlation with relative time of shooting is indicated. The factors involved in both frit attack and blindness are clearly very complex.

not, the writer sees no particular objection to the use of this or other resistant strains of *A. fatua* in crossing experiments, provided that very rigid selection is subsequently carried out.

Acknowledgments

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Summary

A biometric study has been made of the occurrence of blindness or blast in three different strains of oats.

One strain, *A. fatua*, is clearly much less affected by blindness than *A. sativa* var. *Banner* or a strain of false wild oats from Banner.

In three sowings the strain of false wild oats appears to be similar with respect to blast to the variety Banner from which it arose, but in the other two sowings the false wild had significantly more blast.

Fisher's "Intra-class correlation as an analysis of variance" test demonstrates clearly that the difference in proportion of blind spikelets is much greater between similar sized panicles of *A. fatua* and Banner than between different sized panicles of either sort or of the false wild oat.

It is concluded that specific genetic resistance to blindness exists and that differences in degree of blindness are not due to a general physiological correlation with panicle size.

If good blast-resistant varieties of oats do not already exist, it should therefore be possible to produce them by breeding.

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THE INCREASE OF NATIVE INSECTS TO ECONOMIC IMPORTANCE IN THE PRAIRIE PROVINCES.

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The principal insects attacking field crops in Western Canada are native, not introduced, species. This may be ascribed to the comparatively recent development of agriculture in this region, giving a shorter time during which introduction might have taken place and, more importantly, to the extreme climatic conditions which, in agricultural countries, are closely paralleled only in Russia, thus reducing to one the regions from which most danger might naturally have been encountered.

The five pests dealt with in the present paper are the red-backed cutworm, *Euxoa ochrogaster* Gn., the pale western cutworm, *Agrotis orthogonia* Morr., the wheat-stem sawfly, *Cephus cinctus* Nort., the prairie grain wireworm, *Ludius aereipennis tinctus* Kby., and grasshoppers, the three most common species of which are the clear-winged grasshopper, *Camnula pellucida* Scud., the lesser migratory grasshopper, *Melanoplus mexicanus* mexicanus Saus. and the red-legged grasshopper, *M. femur-rubrum femur-rubrum* DeG.

While distributed throughout Canada, the red-backed cutworm causes its greatest damage in the prairie provinces and, as Mr. King and the writer have shown in a previous paper (*4*), is there typically associated with the poplar savanna, that is, the open grassland or cultivated fields dotted with clumps or groves of poplar. The reasons for this association are not definitely established. An important factor, however, seems to be the greater number of plants flowering in late summer and autumn in this zone. Of these the most important are several species of golden-rod (*Solidago* spp.) which are a preferred food for the moths. Since the moths have a well defined pre-oviposition period of a week or more and since the oviposition period may last, with fine weather, for a month or more, the abundance or scarcity of food is a critical factor.

The occurrence of this species as an economic insect was nearly coincident with the development of agriculture in this region, for Dr. Fletcher's report for 1891 (*3*) mentions it as being present in troublesome numbers from Ottawa to Calgary. In five years of fairly intensive collecting of cutworms in Saskatchewan, we never once took *E. ochrogaster* larvae on native sod. The nearest approach to uncultivated conditions in which we took the species was by the side of a little used road where blown soil had accumulated for several years. It is, then, reasonable to assume, unless proved otherwise, that the natural habitat of the larvae was land where the soil surface was loose, a condition most often encountered in light, sandy soils. In cultivating the soil, man provided an immense acreage approaching in type this habitat and, at the same time, planted abundant food for the larvae. It is also generally accepted that, probably

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largely by the prevention of prairie fires, man is in the main responsible for the present southward spread of the poplar savanna in Saskatchewan, thus increasing the territory liable to suffer severe damage.

The pale western cutworm is more local in its distribution, being virtually confined, in Canada, to Saskatchewan and Alberta. In contrast to the red-backed cutworm, it was considered a rare noctuid until 1911 (Parker, Strand and Seamans (*6*)), when an outbreak occurred in southern Alberta. In Seamans' (*7*) discussion of this insect, we find the following:

> "The pale western cutworm is a native prairie insect of the semi-arid regions. It has been widely collected over the prairies, and both moths and larvae have been found at some distance from cultivated areas. Under natural conditions the larvae evidently live above the surface of the ground and feed for the most part on the leaves and stems of native grasses. The various enemies have ready access to the larvae and bring about a natural control. With the cultivation of the soil for crops the larvae have been able to move about below the surface with a certain amount of ease and this species has apparently begun a new mode of life. Instead of moving about and feeding above the ground it now feeds largely upon the stems of plants about an inch below the soil surface and moves about in the softer soil where its various enemies seldom reach it. When the soil is very wet the larvae are forced to the surface, where they remain until it begins to dry out. At such times they are again upon the surface of the soil and are accessible to their enemies."

There is a divergence of opinion on the relative importance of the biological factors active in control in cultivated land, a different theory being advanced by Dr. W. C. Cook (*1*) who, from various studies in the United States, reaches the conclusion that, while the possible importance of insect parasitism must be admitted, bacterial and fungous diseases are of much greater significance. These latter factors commonly cause a high mortality among insects only in heavy infestations and, while Dr. Cook's opinion may now have a large amount of truth in it, it would fail to explain the original increase as does the theory of present control advanced by Seamans. The writer's experience in south-central Saskatchewan, where the insect has become seriously abundant only during the last six years, indicates that there both groups of factors may assume considerable importance.

Mr. Norman Criddle (*2*) has shown how the extensive planting of wheat provides, in the wheat stems, a new habitat for the wheat stem sawfly where its larvae are nearly immune to the attacks of insect parasites, while in wild and cultivated grasses the parasitism is a very considerable factor in keeping the numbers of the insect in check.

The planting of wheat has been responsible in a second manner also for the increase of this insect. When ovipositing, the sawflies show no discrimination between stems already containing eggs and those still untenanted, yet only one larva can survive in each stem. On the native prairie, the number of stems suitable for egg-laying was limited. While around the edges of wheat fields heavy mortality does sometimes occur through several eggs being laid in one stem, a fact made use of in the employment of trap strips, the mortality from this cause throughout a whole field is usually not very heavy unless the infestation is extremely high.

Turning to a consideration of the prairie grain wireworm, we find a condition more analogous to that of the red-backed cutworm. With the

exception of the region of loose top soils in west-central Saskatchewan, damage in the west occurs mainly in fields that have been under cultivation for ten to fifteen years or more, but the evidence indicates that there has been no noticeable change in the habits of the insect and that the less rapid increase is due to the longer life cycle.

Like most wireworms, the species is almost immune to biotic control factors except predators, such as birds and carabids. Both Strickland (*8*) and King (*5*) stress the effects of high temperatures and low soil moisture contents in causing a high mortality among the immature stages, Strickland particularly emphasizing the effect of these factors on the eggs and first instar larvae. The conclusion then drawn is that on the prairie these factors cause a high mortality, while in cultivated soil, and especially in summer-fallow, the beetles can burrow deeper to deposit their eggs, thus placing them where the moisture content of the soil remains higher and where they and the young larvae are more likely to survive. Also, at least in the summer-fallow, destruction of older larvae by dessication, which may occur on the prairie, is completely avoided through the retention of the soil moisture.

Grasshoppers deserve mention in this discussion because they do periodically become a major pest. However, outbreaks used to occur before the advent of the farmer and our immediate interest in this pest is, therefore, not in the causes of increase but in the fact that here is a group of species the importance of which has not been notably changed by agriculture except through the provision of a more abundant food supply, which food is of greater commercial value than the native plants.

Summarizing, we can suggest the following causes of increase: that all five insects benefitted by the provision of an abundant food supply; that, in addition, the red-backed cutworm multiplied owing to a tremendous increase in the extent of a habitat closely resembling the native, and through the extension of the savanna country to which the species is best adapted; that the pale western cutworm increased as the result of adopting a new mode of life when a new habitat was presented and thereby largely escaping its natural enemies; that the wheat-stem sawfly found in wheat a new habitat where it was largely immune to the attacks of its natural enemies and where the mortality resulting from numerous eggs being laid in one stem was reduced; that the prairie grain wireworm finds, in the cultivated land, and particularly in summer-fallow, a habitat where its immature stages experience a much lower mortality from dessication than on the prairie; that grasshopper outbreaks occurred before the advent of agriculture and that, because of this, the proportionate change in population resulting from agriculture has not been nearly as high as for the other insects considered.

It might be inferred, up to the present, that the species considered increased more or less uniformly once the new environmental factors were introduced. In reality no doubt large fluctuations, dependent primarily on the weather, occurred in the rates of increase while now, at least for some of the species, a new approximate balance in numbers, with larger or smaller fluctuations, has again been established. This last appears true

particularly of the red-backed cutworm and grasshoppers and may probably also be applied to the pale western cutworm in the original area of infestation in south-western Saskatchewan and south-eastern Alberta.

Since the insects considered are endemic and have with them their natural complement of parasites, we have, in relation to the introduction of parasites, a rather different problem from that encountered with introduced pests. Any parasites that could be introduced would not naturally have these insects as hosts. Furthermore, owing to what was pointed out about the climate at the beginning of this discussion, the chances of establishing new parasites at all are not as bright as they might be. Therefore, while the possibility of introducing parasites must not be disregarded, the major control efforts must generally be cultural and based on a wide ecological study of the insects concerned, both in their native habitats, when known, and in cultivated fields. Furthermore, where such quantitative ecological studies can be carried on in areas where agriculture. is young, it may sometimes be possible to foresee the danger of an insect becoming a serious pest and to so modify cultural practices as to avoid this.

One further point, concerning the adaptability of insects. Among some entomologists this has become almost a journalistic phrase. The pale western cutworm adapted itself, changing its mode of life, and some may argue that the wheat-stem sawfly showed an adaptation in utilizing a new host plant when offered. But I believe that the majority of noxious insects have become noxious not through any innate change in their habits, any adaptation, but through the changing of one or more factors in their environment which brings this environment closer to the optimum for the species concerned. In any native habitat there are numerous species which are managing to survive under conditions far from their optimum. Change the nature of the habitat and you will shift it towards the optimum of one or more of these species, allowing it to increase and, very possibly, to develop into a pest. It is the old, old, concept of the balance of nature but it is interesting to see what a large part a change in physical, as opposed to biological, factors can play, even if it is sometimes only through these biological factors that the physical changes take effect.

Acknowledgments are due to the published works of the men whose names are mentioned and also to certain unpublished observations by Mr. K. M. King on the red-backed cutworm.

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A PRELIMINARY REPORT OF THE SUBSTITUTION OF PILCHARD OIL FOR BUTTERFAT IN MILK FOR CALF FEEDING.[1]

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Pilchard oil is a relatively cheap source of fat. In British Columbia for the year 1930 the price of this oil was 3⅓ cents per pound, approximately one-tenth of that paid per pound of butterfat in sour cream. Therefore, it was proposed to determine whether or not commercial pilchard oil, as produced in British Columbia, could be used economically as a substitute for the butterfat in milk for rearing calves.

On February 10, 1930 three Jersey calves were obtained from the herd of the University of British Columbia. These calves were housed in a suitable pen with the other calves of the University herd. At the commencement of the experiment, two of the calves were 15 days old and the third 6 days, and had been raised up to this time on a normal ration of whole milk.

The substitution of the commercial pilchard oil (1929 pack) for butterfat was gradually made by replacing each day one-seventh of the whole milk by fresh skim milk into which was emulsified 3.5 per cent of the oil. Therefore, on the eighth and following days all three calves were receiving an ample ration of fresh skim milk containing 3.5 per cent pilchard oil.

The weights of each calf were taken at regular intervals and their general condition recorded daily. During the change from butterfat to pilchard oil all three calves made gains in weight and had a good appetite. However, their general condition was not as good as might be expected with whole milk.

Soon after the calves received the completely substituted milk their condition rapidly fell off, scouring being the first symptom of the toxic-like effect of the oil. The youngest calf died on the twelfth day after the experiment was commenced, one of the others on the thirteenth day, and the third was killed on the fourteenth day to obtain a better post mortem examination, at which time its condition was such that it could have lived only a few hours.

The post mortem examination of all three calves showed severe inflammation throughout the body, especially in the regions of the heart, lungs and intestines.

Though there cannot be said to have been an exact control, the other calves of about the same age, fed on whole milk and kept in the same pen, grew normally and showed none of the above mentioned symptoms.

On December 23, 1930 a second experiment was started which differed from the first in the following modifications. Two Holstein calves and one

1 Abstracted from an undergraduate thesis submitted to the Faculty of Agriculture of The University of British Columbia.
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Jersey were purchased from accredited herds in the neighborhood. At the commencement of the experiment the two Holsteins were each sixteen days old, and the Jersey twenty-two days. These calves were housed in a separate room on the South side of the University dairy barn. To simplify the feeding and to maintain uniformity the milk was reconstituted from a high grade skim milk powder and water, the pilchard oil being emulsified into the same at the rate of 3.5 per cent. By this method the same lot of skim milk powder and commercial pilchard oil (1930 pack) were available throughout the entire experiment and also for feeding small animals.

The substitution of the whole milk for reconstituted milk was done gradually in the same proportions as in the previous experiment, the eighth day of the experiment completing the substitution. The calves received a small amount of alfalfa hay with the milk ration.

The results obtained with this lot of calves are almost a duplication of the first experiment. Increases in weight were obtained during the first week, scouring was the first symptom of the toxic-like effect. Soon after the complete substitution of the butterfact the condition of the calves was very unsatisfactory. One of the Holstein calves died on the fifteenth day of the experiment, the Jersey on the eighteenth day, and the other Holstein calf was killed on the twentieth day of the experiment, at which time its condition was such that it would have died in a day or so.

Both experiments show that the substitution of commercial pilchard oil for the butterfat in milk for feeding young calves resulted in their death.

However, similar results were not obtained with rats. Two females gave birth to and raised normal litters of young, the one on a diet of 25 per cent butterfat, 60 per cent skim milk powder and 15 per cent bran; and the other on the same diet with the exception of substituting commercial pilchard oil for the butterfat. Water was always available and the rations were fed to both mother and young *ad lib.* For the whole of the 50 days of the experiment all the rats appeared in perfect health. The average gains in weight of the young in both groups were similar.

The work herein reported can only be considered as preliminary, but until the exact reason for the death of the calves can be established, the substitution of pilchard oil for butterfat in the diet of young calves cannot be recommended.

This study has carried the work beyond mere feeding trials and presents a fundamental problem in nutrition which is being investigated.

Thanks are tendered to the B. C. Packers Ltd., and the Canadian Milk Products Ltd. for supplies of oil and skim milk powder respectively; also to the J. R. Lister Co. Ltd. for the loan of a Melotte emulsifier.

ECONOMIC ASPECTS OF DROUGHT RESISTANCE

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Science has been occupied for some time in a study of the nature of drought resistance in crops, but has not given equal attention to the practical aspects of the drought problem. This phase of the question is of particular interest to farmers in Western Canada where periodical spells of dry weather cause far more havoc to grain yields than any other factor.

Maximov (*6*) states that the selection of drought-resistant varieties of crops is delayed by the indefiniteness of the conception of drought. "It is necessary", he says, "to distinguish at least two modifications of drought —that of the atmosphere and that of the soil". Atmospheric drought may produce rapid wilting or even dessication of the plant through the action of hot dry winds while ample supplies of moisture are available. Soil drought occurs when the amount of water secured by plants is insufficient to replace the water lost by transpiration.

Most of the investigational work on drought resistance has been conducted by the use of plants in more or less advanced stages of maturity. Recent work has shown that certain physico-chemical properties of the leaf tissue fluids agree very closely with the known drought resistance of various crops. Newton and Martin (*7*) found that the bound-water content of the cell sap enabled them to classify crops in regard to their ability to resist drought. It does not necessarily follow, however, that crops which are drought resistant are the most economical to cultivate in dry areas. Where farmers in such areas are desirous of securing the highest yields of forage,most easily grown, the idea that drought resistant crops should be the obvious choice may be quite erroneous.

The work of Briggs and Shantz (*2*) and Barnes and Hopkins (*1*) shows that the water requirement of grass and clover crops is higher than that of cereal crops, although the former can successfully resist drought. The higher water requirement means that grass and sweet clover are less efficient in the utilization of water and, if grown under similar conditions, would yield less dry matter than cereal crops.

Some idea of the yield of acknowledged drought resistant plants under dry conditions can be obtained from a consideration of the natural grass cover in dry areas. Evidence presented to the Royal Commission (*9*) showed that from 25 to 35 acres of unbroken prairie land in the dry areas of Saskatchewan and Alberta are necessary to maintain one horse or one cow for a year. The common practice among ranchers in these areas is to provide 40 acres of grazing land for each mature animal. In these cases the vegetation probably represents the extreme in drought resistance, as it consists of plants which have survived both competition and prolonged spells of drought. Experiments conducted at the Dominion Experimental Station, Swift Current, Sask., indicate that much greater yields are secured from cereal crops which are relatively non resistant to drought,

[1] Field Husbandman.

used as hay, than from such crops as grass or sweet clover. The results of these experiments are presented in the following table:

Comparative Yields of Forage Crops
Swift Current, Sask.
1924-1930

Corn	100.0
Oats	87.2
Sunflowers	86.9
Wheat	71.4
Brome Grass	48.0
Sweet Clover	46.0

These results have been secured from small plots. On a field scale oats would undoubtedly occupy first place on the list and brome grass and sweet clover a relatively lower position on account of the frequent failure of these crops to make a stand. As all crops are treated as forage crops the grains include both grain and straw. The comparison in each case has been made on the dry matter basis.

The causes of low yields of grass and sweet clover in dry areas can be readily understood from a consideration of the behaviour of soil moisture. The work of Kiesselbach, Russel and Anderson *(4)* has shown that in Eastern Nebraska the yields of alfalfa decline to the level established by the seasonal rainfall as the soil moisture is exhausted. Under the relatively drier conditions prevailing in Western Canada the surface and subsoil moisture is exhausted by the nurse crop. The grass or clover crop is then dependent almost entirely upon the seasonal rainfall for its moisture supply. This, normally, is not sufficient to ensure normal yields, which are only secured in districts receiving relatively high precipitation. The distribution of precipitation is usually such as to hamper the development of the grass or clover. These crops attain their maximum growth relatively early and before the period of maximum amounts of precipitation. Coupled with these difficulties is the fact, previously mentioned, that grass and sweet clover crops are relatively inefficient to the utilization of soil moisture.

Aside from the aspect of relatively low yields of grass and sweet clover in dry areas, there is considerable difficulty in securing stands of these crops. At the Swift Current Station a grass and sweet clover mixture in a crop rotation was successful in 1924, 1925 and 1928, but was a failure in 1923, 1926, 1929 and 1930. In 1927 the second year hay crop was a failure. Experience at the Lethbridge, Alberta, Experimental Station has been no better in this regard. Referring to brome grass, western rye grass and sweet clover the Superintendent remarks in his reports: "The difficulty of getting these crops established in dry years has made their growth hazardous". The difficulty referred to is explained in a later sentence: "The place that these crops can take is still a matter for experimentation, more perhaps to determine the most successful way to obtain a stand than their place in the cropping system". The opinion of a well known "Master Farmer" agrees in all particulars with the foregoing. Mr. T. J. Graham of Pennant, Sask., is quoted in the January 5, 1931 issue of the *Nor'-West Farmer* as follows: "It is out of the question to try and grow clovers or

cultivated grasses on the good prairie wheat soils because of the difficulty experienced in getting a catch in many years, as well as the disappointing yields that follow grass and sweet clover crops if there is a shortage of moisture".

Farmers in the dry areas of Saskatchewan and Alberta have depended chiefly upon oats for their supplies of hay. The choice, apparently, has been a wise one for, according to the results of roughage feeding trials conducted by the Montana Experiment Station *(13)*, oat hay was superior to alfalfa, sweet clover, corn fodder or blue-joint hay. It seems almost incredible that alfalfa should not have proved superior to oat hay, but it must be remembered that alfalfa from dry land is not always of the same high quality as that grown under irrigation or in districts receiving abundant rainfall.

Western Canada comprises such a large area that variations in climatic conditions must be expected. Some districts generally receive abundant rainfall, while in others periodic spells of rainfall deficiency have resulted in their classification under the title of "Dry", although the term does not warrant a strictly literal application. The above discussion refers particularly to these so-called "Dry" areas where the production of grain forms the most important farming practice.

Summary

The ability of certain crops to withstand drought is not necessarily an indication of the adaptability of such crops for dry areas. Farmers in such areas in Western Canada are particularly interested in crops which produce the maximum yields under the adverse conditions created by moisture deficiency. Crops which fulfill these requirements are those which are relatively efficient in the use of water, i.e., those which have a low water requirement.

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THE INHERITANCE OF STEM RUST AND SMUT REACTION AND LEMMA COLOUR IN OATS [1]

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INTRODUCTION

Oats, which are grown the world over as a food for man and domesticated livestock, are of considerable importance in Canada, being exceeded in value only by wheat. The total yield and value of the crop are limited by a number of factors such as soil, moisture, temperature and disease. Among the most destructive agents are two of the disease producing fungi, the rusts and the smuts.

These diseases may be controlled either by the application of chemical substances to the seed or to the growing plant. Since chemical treatments involve expense and are not always successful, the production of resistant varieties appears to be the most economical and effective means of controlling plant diseases. Already much has been accomplished in the production of resistant varieties and in the study of the inheritance of resistance to certain diseases. However, owing to the existence of physiologic specialization in a number of disease producing fungi, the production of resistant varieties has become a complicated process. A fact of great importance to one who seeks to improve plants by breeding for disease resistance, is that this character obeys the same fundamental laws of inheritance as plant characters in general.

LITERATURE REVIEW

Rust Reaction. Among the earliest observations on the variation in susceptibility of varieties to rust are those of Eriksson and Henning (*8*) in Sweden. These writers state that it was impossible to observe any definite difference in the susceptibility of oat varieties. McAlpine (*23*) states that stem rust alone is peculiar to oats in Australia and that the wild oat, *Avena fatua,* is generally severely affected. Vavilov (*47*) made extensive tests on 350 lots of cultivated and wild oats to determine their reaction to both stem and crown rust. From his experiments he concluded that there is little probability of finding varieties resistant to stem rust. In the case of crown rust, however, although the majority of cultivated and wild oats was found to be very susceptible, many more forms showed resistance. One of the earliest American records of rust resistance in oats was that of Speers (*42*) in 1870, who reported the results of his observations on the occurrence of rust on the oat varieties in the Iowa Agricultural Experiment Station plots. Though no mention is made of the species of rust concerned, he states that the oats all rusted so badly they were almost worthless, with the exception of Improved American, Everett, Lackawana and Giant Yellow French. Other early writers who observed

[1] Submitted to the University of Alberta as a thesis in partial fulfilment of the requirements for the degree of Master of Science; granted May 15th, 1930. Work carrried on at the Dominion Rust Research Laboratory, Winnipeg, Man.

[2] Cerealist.

resistance or susceptibility of oat varieties to rust are Pammel (*29*), Plumb (*32*), Carleton (*5*), Bolley (*3*), Shepperd and Ten Eyck (*41*) and McWethy (*25*).

Norton (*27*) published definite experimental results on oat rust resistance and distinguished clearly between crown rust, *Puccinia coronata avenae* (Corda.) Erikss. and Henn., and stem rust, *Puccinia graminis avenae* Erikss. and Henn. He found that *Avena sterilis* forms were comparatively free from crown rust but susceptible to stem rust.

Parker (*30*) studied the resistance of oat varieties to crown and stem rust under greenhouse conditions, using seedlings and mature plants. Of more than 120 strains tested 80 were found to be entirely susceptible to both rusts at both stages of growth. Only two varieties, White Tartarian and Ruakura Rustproof were found to be resistant to stem rust.

In a later work, Parker (*31*) studied the resistance of two oat varieties, Burt and Sixty Day, to both stem and crown rust, together with F_2 hybrids between these two varieties. Most of the inoculations were made on seedlings, but enough were made on plants at the time of heading to show that the results were similar. Both parents were susceptible to stem rust. No resistant segregates were obtained in the F_2 generation.

Durrell and Parker (7) made a comprehensive study of varietal resistance to both crown and stem rusts, both in the field and in the greenhouse. Although the manifestations of resistance to rust in the field and greenhouse were comparable, resistance was more marked in the field. The results of the varietal experiments conducted in the greenhouse indicate that the varieties of the red oat group, *Avena sterilis,* show more resistance to crown rust than those of the common oat group, *Avena sativa.* The most resistant varieties in the species of *Avena sterilis* were found to be Appler and Red Rustproof. The varieties White Russian and Green Russian of the *Avena sativa* group and the strains grown under the names *Avena sativa grisea* and *Avena orientalis mutica* were resistant to stem rust, while the variety Ruakura and *Avena barbata* were resistant to both rusts.

There are apparently more varieties of oats which show resistance to crown rust than to stem rust. Under rust nursery conditions the varieties White Russian, Green Russian, Ruakura and the species *Avena barbata, Avena orientalis mutica* and *Avena sativa grisea* showed a high degree of resistance. The species *Avena barbata* and the varieties Green Russian and Ruakura were the only oats showing marked resistance to both rusts under the conditions of the experiment.

Mackie and Allen (*22*) made a study of the resistance of oat varieties to stem rust. These writers inoculated 217 varieties of oats and the following were found to be resistant: Richland, Ruakura, Snoma, one lot of Green Russian and all lots of White Tartar.

Levine (*20*) made an extensive study during the period 1923-1927 of varietal resistance to stem rust of oats. The following eight varieties, selections and crosses were most resistant during the period under review:

Iogold, Heigira, Richland, Minota × White Tartar (White Russian), White Tartar, Green Mountain, Anthony and Edkin.

A study of the inheritance of resistance to stem rust was first made by Garber (*12*) in 1921. This writer made crosses between White Russian, a resistant variety, and two susceptible varieties, Minota and Victory. There was evidence of a single factor difference between the parents in both crosses and resistance appeared to be dominant.

Garber (*13*) made a more complete study of the above crosses in the F_1, F_2 and F_3 generations. The F_1 plants were resistant and in the F_2 a ratio of three resistant plants to one susceptible was obtained. The breeding behaviour of the third generation substantiated the results obtained in the second. Griffee, 1922 (*17*), obtained similar results.

Stakman, Levine and Bailey (*43*) first investigated the possibility of physiologic specialization in the stem rust of oats, *Puccinia graminis avenae*. From their investigations they concluded that four biologic forms existed and were apparently constant. Furthermore, these writers concluded that the distribution of physiologic forms may be different in different countries, and also may differ even in various regions of the same country. On the other hand, more than one biologic form may occur in the same locality or even on the same plant.

Bailey (*1*) proved definitely that at least five physiologic forms existed in the United States. Gordon and Bailey (*16*) isolated six physiologic forms from Canadian collections. Gordon (*16a*) states that Joanette Strain differs in its reaction to forms 1, 3, 4 and 5 at low (57.4°F) and at high (75.4°F) temperatures.

Hayes *et al* (*18*) studied the inheritance of resistance in three crosses and obtained a segregation in F_2 of three resistant plants to one susceptible.

Dietz (*6*) likewise found resistance to be dominant and due to a single factor difference in crosses between White Tartar × National and White Tartar × Lincoln. In crosses between resistant varieties the F_1 plants were resistant. In the F_2 generation some plants were produced which were more resistant than either parent. The same writer crossed three susceptible and genetically different strains of the Burt oat with White Russian, and obtained varying results. In one cross the F_1 was susceptible and the F_2 segregated in the ratio of 3 resistant to 13 susceptible plants. In another cross the F_1 was resistant and the F_2 segregated in the proportion of 3 resistant plants to 1 susceptible. In still another cross the F_1 was susceptible and the F_2 segregated in the ratio of 1 resistant to 3 susceptible plants.

With the exception of Dietz, in his study with the three different strains of Burt, all investigators have agreed regarding the inheritance of rust resistance. Although physiologic specialization exists within *Puccinia graminis avenae,* a fact which complicates the study of rust resistance and the production of rust resistant varieties, no one as yet has attempted to study the inheritance of the reaction to separate physiologic forms, except Waterhouse (*48a*), who studied the reaction of form 1. In crosses between Belar × Reid, Ruakura × Richland, Algerian × White Tartar, and Algerian

× Joanette, there was a close approach to complete dominance in F_1. The first two crosses mentioned were studied in the F_2 and reaction to form 1 was found to be controlled by a single factor.

Smut Reaction. Previous to the work of Reed (*33*) in 1920 very little study had been made of the resistance of oat varieties to loose smut, *Ustilago avenae*, and covered smut, *Ustilago levis*. This author gives a comprehensive review of the literature regarding early studies on smut resistance, so in the present review the more recent work, only, will be reported.

McAlpine (*24*) successfully infected both wild and cultivated oats with spores of *Ustilago avenae* from wild oats. He also infected wild oats with spores from cultivated oats.

Heald (*19*) reported results with 19 varieties of oats inoculated with spores of *Ustilago levis*. Three varieties of hulless oats (*Avena nuda*) had more than 87 percent infection. Infections ranging from 27.5 to 75.2 percent were shown on 14 varieties mainly *Avena sativa* types. Two varieties showed negative results. One of these, Texas Red, belonged to the *Avena sterilis* group and the other, Kherson, belonged to the *Avena sativa* group.

Vavilov (*46*) reported his observations on the behaviour of a large number of varieties of oats infected with *Ustilago avenae*. The only immune variety of *Avena sativa* obtained by this writer was Mesdag. Under field experiments this variety was found to be free from smut, but under greenhouse conditions he was able to obtain an occasional smutted plant. Vavilov also records resistance to loose smut in *Avena nuda* var. *biaristata*. This variety, unlike other varieties of *Avena nuda* has 14 to 16 chromosomes. He also records one strain of *Avena strigosa* which proved to be susceptible to loose smut.

Reed (*33*) obtained results which coincided very closely with those of Vavilov. The only immune variety, Mesdag, observed by Vavilov appeared to be identical with the variety Black Mesdag used by Reed. The latter described experiments on the resistance and susceptibility of species and varieties of *Avena* to both loose and covered smuts. It was found that all the strains of the species *Avena brevis* Roth., and *Avena strigosa* Schreb., were entirely free from infection. *Avena fatua* L., proved quite susceptible to both smuts, as likewise did the strains of *Avena nuda* L. All the varieties and strains of *Avena sativa orientalis* were moderately susceptible, the infection averaging above 50 per cent. The large number of strains and varieties of *Avena sativa* L., showed a considerable range in the degree of susceptibility to both smuts. A few varieties proved very susceptible, but the majority showed only moderate percentages of infection. Two strains of Black Mesdag consistently showed negative results.

It is especially noteworthy that the highly susceptible varieties were equally susceptible to both smuts, the highly resistant varieties were equally resistant to both smuts, and varieties that consistently showed negative results with one smut behaved similarly towards the other.

Stapledon (*44*) has noted the prevalence of smut in the varieties of oats at the Welsh Plant Breeding Station at Aberystwyth. His results are more significant on the question of contamination of seed than on the problem of varietal resistance. It should be noted, however, that Welsh *strigosa*, belonging to the *Avena strigosa* group, produced some smutted plants.

Sampson and Davies (*40*) have recorded the occurrence of *Ustilago avenae* on 31 varieties in the experimental plots at Aberystwyth, Wales. Fifteen of these, among them the varieties Culberson, Black Mesdag, Golden Rain and Black Mogul, appeared to be quite susceptible. According to these investigators, *Ustilago levis* is rare in Wales, having been found in the experimental plots only on *Avena nuda* var. *chinensis* and *Avena strigosa* sub-species *glabrescens* and *orcadensis*. They carried out an experiment in which they inoculated eight varieties of oats with spores of *Ustilago levis* from Orkney *strigosa*. Infections were obtained on Orkney *strigosa*, but the other seven varieties, Algerian *sterilis*, Welsh *strigosa*, Ceirch du Bach, Black Tartar, Golden Rain, Rodnorshire, Sprig and Potato gave negative results. According to their other records, however, these varieties were severely infected by *Ustilago levis*.

The results obtained by these investigators differ from those of Reed (*33*) in that Black Mesdag and different varieties of *Avena strigosa* were susceptible. Reed obtained varieties of *Avena strigosa* from the Welsh Plant Breeding Station and found that they differed in appearance from the ones with which he worked.

Reed (*35*) in a later work, made a comprehensive study of the varietal resistance of oats to *Ustilago avenae* and *Ustilago levis*. *Avena sativa* was represented by over 90 varieties and 182 strains. These showed great variation in their susceptibility. A few proved to be very resistant including Black Mesdag, Culberson (S.N. 295), Caucasus, Danish Island (S.N. 311) and Siberian (S.N. 323). A large number proved to be highly susceptible; the greatest number, however, could be placed in groups intermediate between the two extremes. Several varieties including Bicknell, Black Diamond, Danish Island, Early Gothland, Rossman and Scottish Chief appeared to manifest a greater susceptibility to *Ustilago avenae* than to *Ustilago levis*. The reverse seemed to be true in the case of C.I. No. 620, Green Russian, Monarch and Tobolsk.

All the varieties of *Avena sativa orientalis* appeared to be susceptible. The wild forms of *Avena sterilis*, were moderately susceptible to both smuts. The cultivated varieties such as Burt Fulghum, Red Rustproof and other varieties possessed a marked resistance to both smuts.

Gaines (*11*) tested 210 varieties and selections of oats for resistance to covered smut, *Ustilago levis*. In general the immune and resistant classes belong to the Burt and Red Rustproof groups. The more resistant classes were usually of Kherson or Sixty Day type. The hulless and common groups were generally found to be susceptible, the outstanding exceptions being three Markton selections and four Red Rustproof × Black Tartarian hybrids which were immune.

Reed (*34*) was one of the first to observe physiologic specialization in both the loose and covered smuts of oats, *Ustilago avenae* and *Ustilago levis*, respectively. He inoculated oat varieties with smut from various sources and found that varieties resistant to smut from one source would be susceptible to smut from other sources. In a later publication, 1927, Reed (*38*) presented further evidence in favour of the existence of physiologic specialization in both smuts.

Wakabayashi (*48*) studied crosses of Red Rustproof, which is immune from covered smut, with Black Tartarian, which is susceptible. Immunity was dominant and it was concluded that several genetic factors were involved. Barney (*2*) in three different crosses suggested that reaction to loose smut could be explained upon a monohybrid, dihybrid and trihybrid basis, respectively. Reed and Stanton (*37*) in crosses between Fulghum which is resistant to both loose and covered smuts, and Swedish Select, which is susceptible, presented evidence which indicated that resistance to both forms was dependent upon the same genetic factors. Both immunity and resistance were dominant over susceptibility. No case of linkage was observed. Gaines (*11*) studied the inheritance of Red Rustproof in four crosses with susceptible varieties. In crosses with Black Tartarian and Abundance the results indicated that Red Rustproof carried three dominant factors for immunity, any one of which prevents the production of covered smut spores. In crosses with Large and Chinese Hulless, one factor apparently did not give complete dominance in hulless segregates, but otherwise the prepotency of the factors for immunity was similar in all four crosses. Reed (*36*) in a cross between a very susceptible *A. nuda* and a resistant *A. sativa*, Black Mesdag, obtained results which indicated that resistance to *Ustilago avenae* is dominant while susceptibility is recessive. The facts seemed to indicate that there was a single factor difference between the two parents. Hayes *et al* (*18*) in a cross between (White Russian × Minota) Minn. No. II-18-37 and Black Mesdag, state that there are separate factors which differentiate immunity and resistance. The results could be explained by two pairs of genetic factors, II and RR, for immunity and resistance, respectively, located in Black Mesdag. I might be considered to be epistatic to R. It was found impossible, however, to determine the exact genetic constitution.

Garber, Giddings and Hoover (*14*) studied the inheritance of smut reaction in a cross between Gopher, which is moderately susceptible to both loose and covered smuts, and Black Mesdag, which is immune. Their data were based on the F_3 and F_4 generations, and the results indicated that resistance to smut is an inherited character with a single main factor difference, operating to determine resistance. In addition to this factor, however, there is at least one other that conditions the expression of the character. Transgressive segregation with respect to susceptibility occurred in the cross. Reed (*39*) studied the inheritance of smut reaction in crosses between varieties resistant and susceptible to both loose and covered smuts; between varieties resistant to covered smut and susceptible to both smuts; between varieties resistant to loose smut and susceptible to both smuts, and between varieties susceptible to both smuts. In a cross between Black

Mesdag, which is resistant to both smuts, and Hulless, which is susceptible, the data in the F_2 and the F_3 suggest a single factor difference for resistance between the two varieties. The F_2 of a cross between susceptible Silvermine and resistant Black Mesdag gave similar results. A similar ratio was obtained when susceptible varieties were crossed with varieties resistant to loose smut, and when crossed with varieties resistant to covered smut. When two susceptible varieties were crossed all the segregates were as susceptible as the original parental varieties.

Inheritance of Colour. Numerous investigators have studied the inheritance of grain colour in oats. Nilsson-Ehle (*26*) made a detailed study of this character in which he showed that there was a monogenic difference in some crosses between black and white, yellow and white, and gray and white. Some crosses between black and white gave in F_2 a digenic ratio of 12 black: 3 gray: 1 white; black and yellow likewise gave a ratio of 12 black: 3 yellow: 1 white. In another cross between Gold Rain, a yellow variety, and Moss which is black, the F_2 consisted of four types; black, yellow, gray and white. Some crosses of gray with yellow gave in F_2, gray, yellow, yellowish gray and white. These results were explained on the assumption of three colour genes S for black, Gr for gray and G for yellow. In another black-white cross the F_2 generation gave a segregation of 15 black: 1 white, indicating that the black colour is produced by either of two duplicate genes S_1 and S_2. In addition to these main genes, there were found several modifying ones, M_1, M_2, etc., which dilute the black colour. This explanation has been repeatedly confirmed by several investigators. Wilson (*49*), Gaines (*10*), Zinn and Surface (*50*), Garber and Quisenberry (*15*),Hayes, Griffee, Stevenson and Lunden (*18*) and Odland (*28*) found monogenic differences between black and white. Surface (*45*) and Love and Craig (*21*) in crosses between a yellow *sativa* and a black *fatua* obtained a segregation of 12 black: 3 gray: 1white. Caporn (*4*) using three varieties of *A. sativa* in crosses with *A. nuda* observed the following ratios in F_2; gray × white =3:1, black × gray = 3:1 or 15:1 and black:gray:white = 60:3:1.

Fraser (*9*) made a cross between Burt, which produces yellowish red grains, and Sixty Day which produces yellow grains. He obtained an intermediate colour in F_1 and in F_2 a ratio of 48 red: 15 yellow: 1 white. The results were explained by supposing Burt to carry two colour genes, R for red and Y for yellow, and the Sixty Day variety one gene, Y^1 for yellow. Apparently R is epistatic to both Y and Y^1.

Purpose of Study

The object of the present investigations is to study the mode of inheritance of various plant characters and to produce high yielding strains of oats resistant to stem rust and smut. Eight physiologic forms of oat stem rust, *Puccinia graminis avenae* (Pers.) Erikss. and Henn., have been identified in Canada. The ultimate aim is to study the inheritance of the mode of reaction to each of these forms and to combine the resistance to all of them in a single variety. Although there is evidence of physiologic specialization within the loose and covered smuts of oats, *Ustilago avenae* (Pers.) Jens. and *Ustilago levis* (K. and S.) Magn. respectively, little

definite information is available regarding the number of forms. Therefore, until further research reveals the necessary information, the process of synthetically building up resistance to specific smut forms is not possible. The production of desirable varieties resistant to smut need not be delayed, however, as certain varieties are known to be resistant when inoculated with composite cultures of the pathogene collected at random in the field.

As the parents used in these studies are either white, yellow or black grained varieties a study of the inheritance of this character, as well as of possible genetic linkages, is undertaken.

Materials and Methods

Materials. The parents, Green Russian R.L.[3] 371, Monarch Strain R.L. 560, Heigira Strain R.L. 559, Richland R.L. 172, Joanette Strain R.L. 561, (Minota-White Russian) × Black Mesdag R.L. 374, Markton R.L. 353, Banner R.L. 179, and Victory R.L. 159 were obtained from various sources. Green Russian was obtained from Professor L. R. Waldron, Fargo, N.D., and Markton from the United States Department of Agriculture. Monarch Strain, Heigira Strain and Joanette Strain are selections made by Bailey (*1*) from Monarch selection (Etheridge), Heigira Rustproof C.I. 1001, and Joanette C.I. 1880, respectively. The strain (Minota-White Russian) × Black Mesdag, was obtained from Dr. H. K. Hayes of the University of Minnesota; Richland, Banner and Victory were obtained from Mr. L. H. Newman, Dominion Cerealist, Central Experimental Farm, Ottawa, Canada.

The rust cultures were obtained at the Dominion Rust Research Laboratory, Winnipeg, Manitoba, from W. L. Gordon, Pathologist in charge of oat stem rust investigations, and the smut cultures from I.L. Conners, formerly pathologist in charge of smut investigations at the same institution.

The varieties used as parents were selected on the basis of their resistance and yielding ability. A summary of the rust and smut reactions and yielding ability of the parents is presented in table 1.

Table 1.—*Reaction of parental varieties to the eight physiologic forms of oat stem rust and to loose and covered smut; together with their yielding ability.*

Parents	Physiologic Rust Forms								Smut		Yielding Ability
	1	2	3	4	5	6	7	8	Loose	Covered	
Green Russian	R	R	R	S	R	S	R	S	S	S	Medium
Heigira Strain	R	R	R	S	R	S	R	S	S	S	Low
Richland	R	R	R	S	R	S	R	S	S	S	"
Monarch Strain	R	R	R	S	R	S	R	S	S	S	"
Joanette Strain	R	S	R	R	X	S	S	S	S	S	"
(Minota-White Russian) x Black Mesdag	SR	SR	S	S	SR	S	S	MR	R	R	"
Markton	S	S	S	S	S	S	S	S	R	R	Medium
Banner	S	S	S	S	S	S	S	S	S	S	High
Victory	S	S	S	S	S	S	S	S	S	S	"

R = resistant, SR = semi-resistant, MR = moderately resistant, S = susceptible, X = heterozygosity.

[3] R.L.=Rust Laboratory number; C.I.=United States Cereal Investigation number.

The data in table 1 show that the three most virulent forms are 4, 6 and 8. To form 6 no varietal resistance has as yet been obtained, consequently it was not included in the inheritance studies. Form 8 likewise was not included in these studies as it has only been very recently isolated. To this form, however, there is moderate resistance in the strain (Minota-White Russian) × Black Mesdag. Fortunately, under field conditions neither of these forms are prevalent. With regard to the other forms there is sufficient varietal resistance to each to build up synthetically resistance to all of them.

In the studies on the inheritance of rust reaction, Green Russian, Heigira Strain, Richland and Joanette Strain were used as the resistant parents, while in the smut inheritance studies Markton and the strain (Minota-White Russian) × Black Mesdag were used. These varieties are comparatively low in yielding ability, so the high yielding varieties, Victory and Banner, were used in crosses with them. In table 2 is a summary of the crosses made and the generations grown.

TABLE 2.—*Crosses made and generations grown.*

Crosses Made	Generations Grown				
Heigira Strain x Banner	F_1	F_2	F_3	F_4	F_5
Heigira Strain x Joanette Strain	F_1	F_2	F_3	F_4	
Joanette Strain x (Minota-White Russian x Black Mesdag)	F_1	F_2	F_3		
Richland x (Minota-White Russian x Black Mesdag)	F_1	F_2	F_3		
Victory x (Minota-White Russian x Black Mesdag)	F_1	F_2	F_3		
Heigira Strain x Monarch Strain	F_1	F_2	F_3		
Green Russian x Victory	F_1	F_2			
Markton x Heigira Strain	F_1	F_2			

Methods. The F_1 of some of these crosses were grown in the greenhouse, others in the field. When grown in the field these plants were sulphur dusted, consequently no rust data were recorded in the first generation. The F_2 and F_3 were grown in five foot rows one foot apart, the seeds being spaced approximately two and a half inches apart in the row and on both sides of each series a guard row of Victory oats was sown. Resistant lines, appearing to be homozygous for plant characters in general, were selected from the F_3 population and grown in a rod row test. In order to obtain pure lines, two or three single plant selections were made from each F_3 line.

Studies of rust resistance were made both in the field and the greenhouse. In the field an artificial rust epidemic was produced by inoculating plants of Victory oats, in the greenhouse, to all forms except 4, 6 and 8. These plants were then transplanted to the field at intervals along the guard rows. A very heavy epidemic was obtained by this method. In the greenhouse, inoculations were made in the seedling stage with the use of an inoculating needle, excellent infections being obtained.

The smut studies were made in the field only. The seeds were inoculated six weeks previous to planting by first thoroughly dusting them with

spores. They were then moistened with the hope that the moisture would carry the spores into the crevices of the hull and at the same time greatly facilitate germination.

The most extensive study in the inheritance of rust reaction was made with the cross Heigira Strain × Banner. The F_1 was grown in the greenhouse during the winter of 1926-27, and the F_2 in the field the following summer. A random sample of 1000 plants was taken and the rust reaction of each plant recorded and an estimate made of the number of factors involved. The progeny of these F_2 plants was divided into two lots, one being inoculated with form 2 in the greenhouse and the other grown in the field the following summer, in order to study field resistance. From the F_3, 87 homozygous rust resistant lines were selected and placed in a rod row test during the summer of 1929. Each plot consisted of three rows and was replicated twice, the centre row only being harvested. As Heigira Strain at this time was known to be resistant to forms 1, 2, 3 and 5 only, 100 resistant and 100 susceptible F_3 lines were inoculated with forms 1, 2, 3 and 5 to compare the inheritance of their reactions with that of form 2, which was previously studied. Later, during the winter of 1930-31, 91 of these resistant lines were inoculated with form 7 which was isolated in 1928, and to which Heigira Strain is resistant.

The Heigira Strain × Joanette Strain cross was made with the object of combining the resistance of these two varieties, by which means it was hoped that the strains resistant to forms 1, 2, 3, 4, 5 and 7 would be produced. The progeny of 136 F_2 plants, of this cross, showing field resistance were inoculated in the greenhouse with form 4.

As the strain (Minota-White Russian) × Black Mesdag is resistant to both loose and covered smuts, it was crossed with Richland and Joanette Strain in order to combine rust and smut resistance. Markton, which is likewise resistant to both loose and covered smuts was crossed with Heigira Strain, for the same purpose. So far, rust data only have been obtained on these crosses.

In a cross Victory × (Minota-White Russian × Black Mesdag) a study of the inheritance of smut reactions was made. In this study 301 F_3 lines were selected at random. Each line was divided into two lots of 50 seeds each, one lot being inoculated with covered smut and the other with loose smut. These were planted in five foot rows, each plot consisting of two rows. The two parent varieties were similarly inoculated and sown side by side, at ten plot intervals. As the varieties Heigira Strain and Monarch Strain are similar in their resistance to stem rust they were crossed together, with the hope that transgressive segregation would take place, whereby resistance to form 6 would be obtained. However, data on the inheritance of lemma colour only, have been obtained as yet. The cross Victory × Green Russian was made with the object of combining resistance and high yield.

An experiment was planned to determine what effect smut infection had on rust development. Accordingly, three rust resistant varieties, Richland, Heigira Strain and White Russian were inoculated with covered

smut and sown in the field where a heavy rust epidemic was produced. Twenty rows of each variety containing 25 seeds were sown and at five row intervals uninoculated seed was sown to serve as a check.

Studies on the inheritance of lemma colour were made in all crosses in which the parents differed in this character.

Correlated studies were made between rust reaction and other plant characters, and between yield and such characters as maturity, heading, strength of straw and height.

Experimental Results

The inheritance of reaction to stem rust and smut, the effect of smut on rust development, the inheritance of lemma colour, the relation between rust reaction and other characters, the rod row data, and miscellaneous correlations will be treated separately in the following discussion.

INHERITANCE OF REACTION TO STEM RUST

Several crosses were studied both in the field and in the greenhouse, and in all cases resistance appeared to be dominant or partially so, and governed by a single genetic factor. In one cross, Heigira Strain × Banner, the inheritance of the mode of reaction to forms 1, 2, 3, 5 and 7 was studied while in another cross, Joanette Strain × (Minota-White Russian × Black Mesdag) resistance to form 4 was studied. In all cases rust reaction was governed by a single factor. In the following discussion each cross will be treated separately.

Heigira Strain × Banner. In this cross a study was made of the mode of inheritance in the F_2 and F_3 in the field and of the F_3 lines inoculated with form 2 in the greenhouse. The results are presented in tables 3, 4 and 5.

Table 3.—*Segregation in F_2 for resistance and susceptibility to stem rust in the field in a cross between Heigira Strain × Banner, and calculation of goodness of fit to a 3:1 ratio.*

Rust Class	Observed	Calculated	Dev.	P. E.	Dev. / P. E.
R S	622 233	641.25 213.75	19.25	8.54	2.25

The following symbols are used throughout: R = resistant, SR = semi-resistant, Seg. = segregating and S = susceptible.

Table 4.—*Breeding behaviour of F_3 lines for reaction to form 2 in a Heigira Strain × Banner cross and calculation of goodness of fit to a 1:2:1 ratio.*

Rust Class	Observed	Calculated	$O-C^2$	$\frac{O-C^2}{C}$
R	157	213	3136	14.7230
Seg.	502	426	5776	13.5587
S	193	213	400	1.8779
			$\chi^2 =$	30.1596

P = very small

The total observed numbers agree fairly well with the calculated, indicating a good agreement to a single factor hypothesis as the deviation is less than three times the probable error.

The agreement is not very satisfactory, but when the resistant and segregating classes are combined the deviation is only 2.3 times its probable error, indicating that the departure from a 3:1 ratio is not particularly significant.

TABLE 5.—*Breeding behaviour of F_3 lines for field rust reaction in a Heigira Strain × Banner cross and calculation of goodness of fit to a 1:2:1 ratio.*

Rust Class	Observed	Calculated	$O-C^2$	$\frac{O-C^2}{C}$
R	211	213.25	5.0625	.023740
Seg.	439	426.50	156.2500	.366354
S	203	213.25	105.0625	.492673
			$\chi^2 =$	.882767

P = high

The high value of P implies a rather good fit to a 1:2:1 ratio.

The data in tables 3, 4, and 5 indicate quite conclusively that resistance in this cross is apparently dominant and governed by a single genetic factor.

The following contingency tables, 6, 7, and 8, show the relation between F_2 and F_3 field reactions and between F_2 and F_3 greenhouse reactions.

TABLE 6.—*Relation between F_2 and F_3 field rust reaction in a Heigira Strain × Banner cross.*

		F_3 Field Reaction			
		R	Seg.	S	Total
F_2 Field Reaction	R	202	416	4	622
	S	9	23	199	231
	Total	211	439	203	853

c = .67

The value of c, the coefficient of contingency, is fairly high indicating a good agreement between F_2 and F_3 field rust reaction. The discrepancies which are evident from the above table are due mainly to errors in classification and to the escape of infection by some plants. The susceptible plants in the F_2 generation, under field conditions in 1927, were not as highly infected as in the succeeding years, as no artificial rust epidemic was produced that year.

TABLE 7.—*Relation between the rust reaction of F_2 plants of a Heigira Strain × Banner cross in the field, and of the F_3 lines inoculated with form 2 in the greenhouse.*

		F_3 Greenhouse Reaction			
		R	Seg.	S	Total
F_2 Field Reaction	R	148	458	15	621
	S	9	44	178	231
	Total	157	502	193	852

c = .62

TABLE 8.—*Relation between the rust reaction of F_3 lines of a Heigira Strain × Banner Cross, under field conditions and in the greenhouse when inoculated with form 2.*

		F_3 Greenhouse Reactions			
		R	Seg.	S	Total
F_3 Field Reaction	R	142	51	3	196
	Seg.	13	404	2	419
	S	2	17	176	195
	Total	157	472	181	810

c = .76

The high values of c, the coefficient of contingency, in tables 7 and 8 show that there is a close relationship between the reaction of F_2 and F_3 lines in the field and of the F_3 lines inoculated with form 2 in the greenhouse. The lack of complete association which is evident from the data in both tables may be due principally to one or more of the following reasons: errors in classification, faulty recording, mechanical mixtures, and possibly to natural crossing. However, the data indicate fairly conclusively that in this cross there is a complete lack of mature plant resistance acting independently of seedling resistance. Goulden, Neatby and Welsh (*16b*) report that in the wheat cross H-44-24 × Marquis, mature plant resistance acted independently of seedling resistance. The discovery of this type of resistance is extremely important, as it indicates that in such a cross seedling reactions are of no value when breeding for resistance. It would appear also, that the factor which controls the reaction to form 2 in the greenhouse is the same as the one that operates in the field. As the field epidemic was caused by several forms the results suggest that the factor which governs the reaction to form 2 also governs the reaction to the forms 1, 3, 5 and 7.

In order to test this hypothesis, 100 susceptible and 100 resistant F_3 lines of the Heigira Strain × Banner cross, were selected on the basis of their field reaction and reaction to form 2 in the greenhouse, and inoculated separately with forms 1, 3, and 5. The data for this experiment are given in table 9.

TABLE 9.—*The rust reaction of lines of a Heigira Strain × Banner cross under field conditions and in the greenhouse, inoculated in F_3 with form 2 and in F_4 with forms 1, 3 and 5.*

No. of Families Tested	Field Reaction	Greenhouse Reaction — Physiologic Forms			
		1	2	3	5
100	S	S	S	S	S
100	R	R	R	R	R

The data in table 9 show that all lines which were susceptible in the field, and to form 2 in the greenhouse were also susceptible to forms 1, 3, and 5, and likewise all lines showing resistance in the field and to form 2 in the greenhouse, were resistant to the same three forms. At the time these inoculations were made form 7 had not been isolated, so

later, during the season of 1930, 91 of the above mentioned resistant lines, the susceptible ones having been previously discarded, were inoculated with form 7. The results obtained showed that these lines were also resistant to this form. Therefore the evidence that forms 1, 2, 3, 5 and 7 are inherited as a group and controlled by a single factor is quite conclusive.

Heigira Strain × Joanette Strain. In this cross the object is to build up synthetically resistance to forms 1, 2, 3, 4, 5 and 7. As has been previously stated Joanette Strain is resistant to form 4 and Heigira Strain to the other five forms. In 1928, field rust data, in which form 4 was not present, were taken on a random sample of 1781 F_2 plants. Of this number 1357 were resistant and 424 susceptible. On the basis of a 3:1 ratio the deviation from the theoretical was 21.25 ± 12.72 indicating a good agreement with a single factor hypothesis.

From the F_2 population 136 resistant plants were selected and in F_3 inoculated in the greenhouse with form 4. From this number 22 resistant, 63 segregating and 51 susceptible lines were obtained. On the basis of a 9:7 ratio the deviation from the theoretical was 8.50 ± 3.90, indicating a fair agreement with this hypothesis. The results are presented in table 10.

TABLE 10.—*Breeding behaviour of F_3 lines for reaction to form 4 in a Heigira Strain × Joanette Strain cross, and the calculation of goodness of fit to a 9:7 ratio.*

Rust Class	Observed	Calculated	Dev.	P. E.	Dev. / P. E.
R	85	76.5	8.50	3.90	2.18
S	51	59.5			

As the numbers studied were small, no conclusions can definitely be drawn regarding the number of factors controlling the reaction to form 4. At the time the inoculations were made nothing was known concerning the effect of temperature on the reaction of form 4 to Joanette Strain in the seedling stage. Gordon (*16a*) states that below 60°F. Joanette Strain in the seedling stage was resistant to form 4, while at higher temperatures the reaction was inconsistent. However, as the lines were inoculated the latter part of April, 1928, a month when the sunshine is quite strong and the temperature of the greenhouse consequently high, the evidence is fairly conclusive that the resistance obtained is absolute. At the present time, however, it is only assumed that these lines are resistant to form 4, further work being necessary before definite conclusions can be drawn.

The resistant lines were inoculated with forms 1, 2, 3, 5 and 7 in the greenhouse and their reactions compared with that in the field. In all cases there was a close agreement. The results are summarized in table 11.

The data in table 11 show that in this cross also, field and greenhouse reactions are closely associated, and further, that resistance to forms 1, 2, 3, 5 and 7 is controlled by the same genetic factor.

TABLE 11.—*The rust reaction of 21 lines of a Heigira Strain × Joanette Strain cross, apparently resistant to form 4, inoculated both in the field and the greenhouse to forms 1, 2, 3, 5 and 7.*

Strain No.	Field Reaction	Greenhouse Reaction to Physiologic Forms				
		1	2	3	5	7
10	R	R	R(1)S	R(1)S	R	R
12	"	"	R	R	"	"
14	"	"	"	"	"	"
17	"	"	"	"	"	"
18	"	"	"	"	"	"
21	"	"	"	"	R(1)S	"
31	"	"	"	"	R	"
34	"	"	"	"	"	"
37	"	"	"	"	"	"
67	"	"	"	"	"	"
115	"	R(1)S	"	"	"	"
9	Seg.	Seg.	Seg.	Seg.	Seg.	Seg.
28	"	"	"	"	"	"
30	"	"	"	"	"	"
35	"	"	"	"	"	"
36	"	"	"	"	"	"
39	"	"	"	"	"	"
44	"	"	"	"	"	"
59	"	"	"	"	"	"
61	"	"	"	"	"	"
75	"	"	"	"	"	"

Joanette Strain × (Minota-White Russian × Black Mesdag.) The object of this cross is to combine rust resistance to form 4 with resistance to both loose and covered smuts. No field rust reaction was recorded as neither of the parents show much resistance to the other forms. In order to study the inheritance of the mode of reaction of form 4 in this cross, a random sample of 1000 F_2 plants was harvested and their F_3 progeny studied in the greenhouse. The temperature was controlled as far as possible, owing to the effect of temperature on the reaction of Joanette Strain to form 4. In spite of this precaution inconsistent infections resulted. However, sufficient data were obtained on 225 lines to indicate that resistance to form 4 is governed by a single factor. The results are presented in table 12.

TABLE 12.—*Breeding behaviour of F_3 lines for reaction to form 4 in a Joanette Strain × (Minota-White Russian × Black Mesdag) cross, and calculation of goodness of fit to a 1:2:1 ratio.*

Rust Class	Observed	Calculated	$O\text{-}C^2$	$\frac{O\text{-}C^2}{C}$
R	75	56.25	351.5625	6.2500
Seg.	90	112.50	506.2500	4.5000
S	60	56.25	14.0625	.2500
			$\chi^2 =$	11.0000

P = .004

The low value of P indicates a very poor fit on the basis of a 1:2:1 ratio, but when the resistant and segregating classes are combined the deviation from the theoretical is 3.75 ± 4.38. Therefore, from the results obtained on the basis of a 3:1 ratio, it is safe to assume that a single factor governs the reaction to form 4 in this cross. Although the primary object was to combine rust and smut resistance, no smut studies have as yet been made.

Richland × (Minota-White Russian × Black Mesdag). Richland which is resistant to all forms except 4, 6 and 8 was crossed with the strain (Minota-White Russian) × Black Mesdag to combine rust and smut resistance. So far rust data only have been obtained. The F_2 and F_3 of this cross have been studied, and in both cases resistance was governed by a single factor. In table 13 data are presented on 958 F_2 plants and in table 14 on 176 F_3 lines.

TABLE 13.—*Segregation in F_2 for resistance and susceptibility to stem rust in the field, in the cross Richland × (Minota-White Russian × Black Mesdag), and the calculation of the goodness of fit to a 1:2:1 ratio.*

Rust Class	Observed	Calculated	O-C	$\frac{O\text{-}C^2}{C}$
R	251	239.50	132.25	.5522
SR	452	479.00	729.00	1.5219
S	255	239.50	240.25	1.0031
			$\chi^2 =$	3.0772

P = .22

The value of P indicates that the departure from a 1:2:1 ratio is not particularly significant and when the resistant and semi-resistant classes are combined the fit to a 3:1 ratio is very good as the deviation is only 1.73 times the probable error.

TABLE 14.—*Breeding behaviour of F_3 lines for field rust reaction in the cross Richland × (Minota-White Russian × Black Mesdag), and calculation of goodness of fit to a 1:2:1 ratio.*

Rust Class	Observed	Calculated	O-C	$\frac{O\text{-}C}{C}$
R	53	44	81	1.8409
Seg.	82	88	36	.4091
S	41	44	9	.2045
			$\chi^2 =$	2.4545

P = .30

The value of P is indicative of a fairly good fit. When the resistant and segregating classes are combined the fit to a 3:1 ratio is very good as the deviation is only 3 ± 3.87.

Victory × *Green Russian.* In this cross the object is to combine the resistance of Green Russian with high yield which is characteristic of Victory. From the F_2 population 1498 plants were taken at random of which 1087 were resistant and 411 susceptible. On the basis of a 3:1 ratio the deviation divided by the probable error was 36 ± 3.23 indicating a fairly wide departure from this hypothesis. Further studies must be undertaken in F_3 in order to determine the true breeding behaviour of these plants.

Markton × *Heigira Strain.* The object of this cross is to combine the rust resistance of Heigira Strain with the smut resistance of Markton. So far rust reactions only have been studied. From the F_2 population 1344 plants were taken at random and the rust reaction of each recorded. Of this number 1037 were resistant and 307 susceptible. On the basis of a 3:1 ratio the deviation divided by the probable error was ± 2.72 indicating a fair agreement with a single factor hypothesis.

RELATION BETWEEN RUST REACTION AND OTHER CHARACTERS

Heigira Strain × *Banner.* The relationships between rust reaction, maturity, and lemma colour were studied in this cross. The significance of these relationships was determined by the χ^2 test. The data are presented in tables 15, 16, 17 and 18.

TABLE 15.—*Relation between rust reaction and maturity of F_2 plants in a Heigira Strain × Banner cross.*

F_2 Rust Reaction	F_2 Maturity in Days: 46-51	52-53	54-56	56-57	58-59	60-63	Total
R	46	194	200	96	25	12	573
S	12	65	81	33	13	9	213
Total	58	259	281	129	38	21	786

$\chi^2 = 5.9187$ P = .41

TABLE 16.—*Relation between days to maturity and field rust reaction in* F_3 *lines of a Heigira Strain × Banner cross.*

F_3 Rust Resistance	F_3 Maturity in Days: 66.5	68.5	70.5	72.5-74.5	Total
R	8	14	12	9	43
Seg.	9	24	41	26	100
S	4	15	15	14	48
Total	21	53	68	49	191

$\chi^2 = 6.4115$ P = .38

TABLE 17.—*Relation between rust reaction and lemma colour in F_3 lines of a Heigira Strain × Banner cross.*

F_3 Colour	F_3 Rust Reaction: R	Seg.	S	Total
White	18	41	20	79
Seg.	26	50	26	102
Yellow	4	10	1	15
Total	48	101	47	196

$\chi^2 = 2.9890$ P = .56

The high value of P in all of the above tables shows that there is no association between maturity and rust reaction, maturity and lemma colour, or between rust reaction and lemma colour.

Joanette Strain × (*Minota-White Russian* × *Black Mesdag*). The relation between lemma colour and resistance to form 4 was studied in this cross. Joanette Strain is black, and (Minota-White Russian) × Black Mesdag is white. The results are presented in table 18.

TABLE 18.—*Relation between lemma colour in F_2 and resistance of F_3 lines to form 4 in a Joanette Strain × (Minota-White Russian × Black Mesdag) cross.*

Rust Reaction to form 4	F_2 Lemma Colour: Black	Gray	White	Total
R	47	11	7	65
Seg.	71	6	4	81
S	44	5	4	53
Total	162	22	15	199

$\chi^2 = 5.8184$ P = .22

The high value of P in table 18 also indicates that no relationship exists between lemma colour and reaction to form 4.

INHERITANCE OF SMUT REACTION

The inheritance of smut reaction was studied in the cross Victory × (Minota-White Russian × Black Mesdag) strain. Victory is susceptible to both loose and covered smuts, while the other parent is immune. The F_3 of this cross, only, was studied. In 1929, 301 F_2 plants were selected at random, 50 seeds of each being inoculated with loose smut and 50 with covered smut. Sufficient seed for checks of the two parent varieties was similarly treated. These were planted in five-foot rows, each plot consisting of two rows of 25 seeds each. At ten plot intervals the two parent varieties were sown. In recording the data the total number of plants in the plot and the total number showing smut infection were counted and the results expressed in per cent.

The infections obtained, on the whole, were not high. Infections on the susceptible parent ranged from 4.4 to 23.8 per cent for loose smut and from 2.2 to 28.9 for covered smut, while the resistant parent was completely immune. One hundred and eighteen of the F_3 lines were immune to loose smut, 31 of which were more or less susceptible to covered smut. One hundred and twenty-six were immune to covered smut, 39 of which were more or less susceptible to loose smut, while 87 lines were immune to both. This condition is more clearly shown if the data are arranged in the form of a 2 × 2 fold table. Table 19 gives such an arrangement of the data.

TABLE 19.—*Frequencies of resistant and susceptible lines to both loose and covered smut.*

Covered Smut	Loose Smut: Resistant	Susceptible	Total
Resistant	87	39	126
Susceptible	31	144	175
Total	118	183	301

$\chi^2 = 80.9920$ P = less than .01

The low value of P indicates quite conclusively that a correlation exists between the infection capabilities of both loose and covered smuts. Accordingly the relation between the percentage infection in both smuts was determined. A correlation coefficient of .683 ± .021 was obtained, a value which leaves no doubt but that such a relationship exists; it also suggests that, in this cross, the reaction to loose and covered smut is controlled by the same factor or factors, or are linked in inheritance. The distributions are shown in table 20.

TABLE 20—*Distribution showing the relationship between the percentage infection in both loose and covered smuts in 301 F_3 lines in a Victory × (Minota-White Russian × Black Mesdag) cross.*

Percentage of Covered Smut	Percentage of Loose Smut													
	0.0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.9	57.5	Total
0.0	87	14	18	4	3									126
2.5	17	21	19	8	1	1								67
7.5	8	12	8	10	4	1	1			1				45
12.5	6	4	3	6		3	1			1				24
17.5		2	3	4	2	2				2			1	16
22.5			1	1	1	1	3	3	1		1			12
27.5					1				1	1				3
32.5				1		1	1					1		4
37.5														
42.5						1								1
47.5								1	1					2
52.5														
57.5							1							1
Total	118	53	52	34	12	10	7	4	3	5	1	1	1	301

$r = .683 \pm .021$

TRANSGRESSIVE SEGREGATION

Twenty-two of the F_3 lines inoculated with loose smut and eight inoculated with covered smut, contained a distinctly greater percentage of smutted plants than did the susceptible parent, indicating that transgressive segregation had taken place. The distributions of parents and F_3 lines for reaction to loose and covered smut are presented in table 21.

It seems probable that the (Minota-White Russian) × Black Mesdag parent possesses one or more factors for susceptibility, and that the Victory parent has a factor which prevents complete susceptibility. On this assumption when the susceptible factor carried by the (Minota-White Russian) × Black Mesdag parent is associated with the susceptible factor of the Victory parent, increased susceptibility occurs. It is assumed that the (Minota-White Russian) × Black Mesdag parent is of the genetic constitution, RRss and the Victory parent rrSS and that the double recessive rrss causes increased susceptibility.

In order to determine more completely the mode of inheritance of smut reaction in this cross a detailed analysis of later generations will be undertaken.

The differentiation between resistant, segregating, and susceptible classes is difficult with a character like reaction to smut which is not completely expressed in the progeny. However, resistant, semi-resistant and

TABLE 21.—*Distribution of the F_3 lines and the two parent varieties for reaction to loose and covered smut.*

Parents and F_3 lines	0.0 0.0	1.0 4.9	5.0 9.9	10.0 14.9	15.0 19.9	20.0 24.9	25.0 29.9	30.0 34.9	35.0 39.9	40.0 44.9	45.0 49.9	50.0 54.9	55.0 59.9
Loose Smut													
Parents:													
Victory	–	1	5	12	8	3	–	–	–	–	–	–	–
(Minota-White Russ.) × Bl. Mesdag	29	–	–	–	–	–	–	–	–	–	–	–	–
F_3 lines	118	53	52	34	12	10	7	4	3	5	1	1	1
Covered Smut													
Parents:													
Victory	–	2	6	6	6	7	2	–	–	–	–	–	–
(Minota-White Russ.) × Bl. Mesdag	29	–	–	–	–	–	–	–	–	–	–	–	–
F_3 lines	126	67	45	24	16	12	3	4	–	1	2	–	1

susceptible classes were formed by classing all lines showing no smut infection as resistant, those showing more infection than the susceptible parent as susceptible, and those showing infections within the two extremes of the susceptible parent as semi-resistant.

By grouping the resistant and semi-resistant classes a very good fit was obtained on the basis of a 15:1 ratio in the lines inoculated with loose smut, the deviation from the theoretical being 3.19 ± 2.83. On the other hand, the deviation from a 15:1 ratio in the lines inoculated with covered smut was 10.81 ± 2.83, a fairly wide departure from the theoretical. When the loose and covered smut classes are combined the deviation from a 15:1 ratio is 7.63 ± 4.01. The results are presented in table 22.

As only the F_3 of this cross has been studied it is difficult to suggest a genetical hypothesis to explain the results. However, it is evident that two factors at least govern smut reaction and that resistance is dominant.

EFFECT OF SMUT ON RUST DEVELOPMENT

In this study two rust resistant varieties, Heigira Strain and Richland, and one moderately resistant variety, White Russian, were inoculated with *Ustilago levis* (K and S) Mag. These were planted in the hybrid nursery and subjected to an artificial epidemic of stem rust. Twenty rows of each variety containing 25 seeds each were sown and at five row intervals uninoculated seed was sown to serve as a check.

When all plants had headed those showing smut infection were pulled. Then, in order to compare the amount of rust infection on smutted and smut free plants, a similar number was taken at random, from the checks

TABLE 22.—*Breeding behaviour of F_3 lines for reaction to loose and covered smuts, and for both smuts combined in a Victory × (Minota-White Russian × Black Mesdag) cross, and the calculation of goodness of fit to a 15:1 ratio.*

Smut Class		Observed	Calculated	Dev.	P. E.	Dev. / P. E.
Loose Smut	R	279	282.1875	3.19	2.83	1.12
	S	22	18.8125			
Covered Smut	R	293	282.1875	10.81	2.83	3.81
	S	8	18.8125			
Loose and Covered Smut	R	572	564.3750	7.63	4.01	1.91
	S	30	37.6250			

and from those plants inoculated but smut free. As the two resistant varieties, Richland and Heigira Strain, under heavy rust conditions show about 5 per cent rust infection, plants showing the same amount were classed as rust free, while those showing higher percentages were classed as rusted. The two rust classes were fairly easy to determine, although the differences were not great. The contrast between the rust free and rusted plants was mainly due to increase in number of pustules rather than in size.

While this project was not conducted on a very extensive scale, the results obtained indicate that smut infected plants are, to a certain extent, more heavily rusted than those non-infected. The results of the investigation are presented in table 23.

TABLE 23.—*Showing the percentage of plants rusted when smutted and when inoculated but smut free.*

Treatment	Percentage Plants Rusted		
	Richland	Heigira Strain	White Russian
Check	15.4	52.2	100
Smut free	11.5	56.5	100
Smutted	73.1	91.3	100

The White Russian variety, owing to the presence of an artificial rust epidemic in which forms 3 and 7 were included and to which this variety is susceptible, was heavily infected, and no perceptible differences were observed in the amount of rust infection between smutted and non-smutted plants. However, the results obtained with the other two varieties, Richland and Heigira Strain, show that rust infection is greater on smutted than on non-smutted plants. Richland showed a difference in rust infection percentage of 61.6 between smutted plants and plants inoculated but non-smutted, and a difference of 57.7 between infected plants and the

checks. A similar difference, though less marked, was obtained with Heigira. In this variety, the difference in rust infection percentage between smutted and inoculated but non-smutted plants was 34.8 and between the smutted plants and the checks there was a difference of 39.1.

In order to obtain a measure of the significance of this result the χ^2 test was applied to the actual numbers obtained in the Heigira and Richland varieties. The results are presented in tables 24 and 25.

TABLE 24.—*Showing the measure of significance in Heigira, of the number of plants rusted when smut infected, and smut free.*

STEM RUST

	Rust Free	Rusted	Total
Check	22	4	26
Smut free	23	3	26
Smutted	7	19	26
Total	52	26	78

$\chi_2 = 27.89765$ P = less than .01

TABLE 25.—*Showing the measure of significance in Richland, of the number of plants rusted when smut infected, and smut free.*

STEM RUST

	Rust Free	Rusted	Total
Check	11	12	23
Smut free	10	13	23
Smutted	2	21	23
Total	23	46	69

$\chi_2 = 9.52122$ P = .01

The low value of P in both tables indicates quite conclusively that the results obtained are highly significant.

INHERITANCE OF LEMMA COLOUR

A study of colour inheritance was made in three different crosses. It should be pointed out that the primary object of these crosses was to obtain resistance to rust and smut, consequently the study of colour inheritance was considered as secondary in importance and was, therefore, not studied in detail in successive generations. No data were recorded on the F_1 of these crosses. The F_2 was studied in all three crosses, and the F_3 in one, only. The three crosses will be treated separately in the following discussion.

Heigira Strain × *Banner*. This cross is between yellow and white grained varieties, Heigira Strain being the yellow parent. Colour data were taken on 196 F_3 lines selected at random and later on 91 F_2 plants other than those studied in F_3, as no greater number was available. From the F_2 plants 74 whites and 17 yellows were obtained. On the basis of a 3:1 ratio the deviation divided by the probable error was 2.06, indicating a fair agreement with a single factor hypothesis. The F_3 results, however, differ from those in F_2 as out of 196 lines, 78 white, 103 segregating and 15 yellows

were obtained, indicating that two factors are operative. On the basis of a 7:8:1 ratio, a P value of .47 was obtained which suggests a good fit to this hypothesis. The data are given in table 26.

TABLE 26.—*Breeding behaviour of* F_3 *lines for lemma colour in a Heigira Strain* × *Banner cross, and the calculation of the goodness of fit to a 7:8:1 ratio.*

Lemma Colour	Observed	Calculated	$O\text{-}C^2$	$\frac{O\text{-}C^2}{C}$
White	78	85.75	60.0625	.7004
Seg.	113	98.00	25.0000	.2551
Yellow	15	12.25	7.5625	.6174
			χ^2 =	1.5729

P = .47

The goodness of fit was also calculated on the basis of a 15:1 and a 9:7 ratio and in both cases good agreements were obtained.

From the data in the above table it appears that white is dominant over yellow. With regard to the number of factors concerned the F_2 and F_3 do not agree, but as the numbers in the F_2 are small no definite conclusions can be drawn from them. On the other hand, the results in the F_3 indicate quite strongly that two factors are operative.

Richland × (*Minota-White Russian* × *Black Mesdag*). This cross is also between yellow and white grained varieties, Richland being the yellow parent. Data were taken on 535 F_2 plants and on 139 F_3 lines which were selected at random. Of the F_2 plants, 320 were yellow and 215 white. On the basis of a 9:7 ratio the deviation from the theoretical was 19.06 ± 7.47, indicating that the departure from this hypothesis is not particularly significant. The ratio further suggests that yellow is dominant over white or partially so.

The results obtained from the F_3 lines entirely disagree with those of the F_2 as a good fit was obtained on the basis of a 1:2:1 ratio. The results are presented in table 27.

TABLE 27.—*Breeding behaviour of* F_3 *lines for lemma colour in a Richland* × (*Minota-White Russian* × *Black Mesdag*) *cross and the calculation of goodness of fit to a 1:2:1 ratio.*

Colour	Observed	Calculated	$O\text{-}C^2$	$\frac{O\text{-}C^2}{C}$
White	34	34.75	.5625	.01619
White-Yellow	74	69.50	20.2500	.29137
Yellow	31	34.75	14.0625	.40468
			χ^2 =	.71224

P = .70

It is difficult with a character like lemma colour to differentiate accurately between yellow and white. It is quite possible that a number of the F_2 plants are wrongly classified, as the breeding behaviour in F_3 indicates that a single factor governs the inheritance of colour in this cross.

Joanette Strain × (*Minota–White Russian* × *Black Mesdag*). The parents of this cross are black and white grained varieties, Joanette Strain being black. In this cross the F_2 only has been studied. Data were taken on 884 plants selected at random, 672 of which were black, 160 gray and 52 white. On the basis of a 12:3:1 ratio a P of .78 was obtained, indicating a good agreement with this hypothesis. According to this theory Joanette Strain carries two dominant factors, B for black and G for gray, black being epistatic to gray. The genetic constitution of the two parents is therefore BBGG and bbgg. Table 28 contains the observed and calculated numbers from this cross.

TABLE 28.—*Segregation in F_2 for lemma colour in a Joanette Strain × (Minota-White Russian × Black Mesdag) cross, and the calculation of goodness of fit to a 12:3:1 ratio.*

Colour	Observed	Calculated	$O\text{-}C^2$	$\frac{O\text{-}C^2}{C}$
Black	672	663.00	81	.12
Gray	160	165.75	33.0625	.20
Yellow	52	55.25	10.5625	.19
			χ^2 =	.51

P = .78

Heigira Strain × *Monarch Strain*. This cross is between yellow and black grained varieties, Monarch Strain being the black parent. Inheritance of colour in this cross was studied in the F_2 only. Data were taken on a random sample of 896 plants of which 670 were black, 128 white and 98 yellow. These numbers were fitted to a 12:3:1 ratio, but a very low value of P was obtained. The data are presented in table 29.

TABLE 29.—*Segregation in F_2 for lemma colour in a Heigira Strain × Monarch Strain cross, and the calculation of goodness of fit to a 12:3:1 ratio.*

Colour	Observed	Calculated	$O\text{-}C^2$	$\frac{O\text{-}C^2}{C}$
Black	670	672	4	.005952
White	128	168	1600	9.523810
Yellow	98	56	1764	31.500000
			χ^2 =	41.029762

P = less than .05

There are too many individuals in the yellow class but as it is difficult to differentiate between yellow and white seeds, the poor fit is considered to be due, largely, to errors in classification. But when the white and

yellow classes are combined, the deviation is 2 ± 8.74 indicating an almost perfect fit to a 3:1 ratio. However, as grains definitely white and definitely yellow were observed, it is fairly safe to assume that two factors govern the inheritance of colour in this cross.

ROD ROW DATA

Data on such plant characters as date of heading, percent rust, strength of straw, height, maturity, yield and percentage hull, were taken on several strains of two crosses, namely, Heigira Strain × Banner and Heigira Strain × Joanette Strain; and on a number of standard varieties, all of which were grown in rod row tests. Data on the strains of the Heigira Strain × Banner cross and on a number of standard varieties were obtained at the Dominion Experimental Farm, Morden, Manitoba, during the summer of 1929, a year in which very little stem rust was present. No artificial rust epidemic was produced, consequently the yields obtained on the varieties and strains were not a test of their yielding ability, under rust conditions. A number of these strains and varieties, together with 21 strains of a Heigira Strain × Joanette Strain cross were grown in a rod row test the following year at the Dominion Rust Research Laboratory, Winnipeg, Manitoba. A heavy rust epidemic was produced, infections as high as 87 per cent being obtained on susceptible varieties. Data on the

TABLE 30.—*Data on 10 standard varieties grown in a rod row test during the summer of 1929 and 1930.*

Varieties	Year	Heading	% Rust	Strength of Straw	Height	Maturity	Yield in Bushels	% Hull
Heigira Strain	1929	62	5	68	37	95	65	24
	1930	45	5	75	32	73	49	25
Iogold	1929	64	5	75	33	96	65	24
	1930	44	5	78	30	71	71	26
Alaska	1929	62	10	77	38	95	47	20
	1930	43	87	58	35	73	37	26
Banner	1929	69	18	80	39	101	80	26
	1930	52	87	83	38	79	22	43
O.A.C. No. 3	1929	63	15	68	33	96	45	19
	1930	45	85	65	31	70	32	29
O.A.C. No. 72	1929	69	18	78	40	103	81	23
	1930	53	85	72	41	81	28	41
O.A.C. No. 144	1929	70	17	80	41	102	73	25
	1930	54	85	75	43	83	19	38
Star	1929	68	18	80	38	101	84	24
	1930	52	83	78	38	76	19	26
Victory	1929	69	13	82	39	102	86	28
	1930	53	85	78	39	79	24	54
White Russian	1929	69	5	85	39	104	67	26
	1930	53	80	82	39	89	35	38

standard varieties and the strains of each cross will be treated separately in the following discussion.

Standard Varieties. A comparison of the data on 10 standard varieties grown in a rod row test during the summer of 1929 when very little rust was present and during the summer of 1930 when a heavy rust epidemic exisited, is shown in table 30.

In table 30 complete data are given for all plant characters. The important feature, however, is the extent to which the yield of a heavily rusted variety is decreased and the percentage of hull increased. Varieties like Banner, O.A.C. No. 72, Star and Victory which under normal conditions produce high yields, are rendered worthless when heavily infected by rust. The yields of the earlier susceptible varieties, Alaska and O.A.C. No. 3, are not quite as low in yield as those of the later maturing ones. This is due, in part, to the fact that they were more advanced in maturity at the time rust infections took place. Another feature worthy of mention is that the growing season was much shorter in 1930 than in 1929. This factor may also have been influential to a certain extent in reducing yields.

Strains of a Heigira Strain × Banner Cross. From this cross 87 rust resistant lines were selected in F_3 and grown in a rod row test during the summer of 1929 along with the standard varieties mentioned in table 30. As was previously mentioned, no rust was present in the field that summer. Therefore, an excellent opportunity was afforded to compare the yields of these strains with those of the high yielding commercial varieties under normal conditions. The results obtained were gratifying as six of the strains produced higher yields than Banner. There was considerable difference in the yields produced by the parents, Banner yielded 80 bushels and Heigira Strain 65. The range in yield for the 87 strains was 84 to 41 bushels. Data on the parents and highest yielding strains are given in table 31.

TABLE 31.—*Data on seven strains of a Heigira Strain × Banner cross, resistant to forms 1, 2, 3, 5 and 7; together with the two parental varieties grown in rod rows in 1929.*

Varieties and Strains	Heading	% Rust	Strength of Straw	Height	Maturity	Yield in Bushels
361	65	0	77	39	98	84
476	66	0	78	40	98	83
301	67	0	77	40	99	83
600	68	0	77	40	100	81
853	66	0	82	37	99	80
490	66	0	77	36	99	80
107	65	0	77	37	99	79
Heigira Strain	62	0	68	37	95	65
Banner	69	18	80	39	101	80

In table 31 all the strains are shown to be free from rust. There was never more than a trace of rust found on any of them, and they were simply marked zero.

The following year, 1930, 66 of the strains of this cross were given a further yield test, at the Dominion Rust Research Laboratory, Winnipeg,

Manitoba, under ideal rust conditions. The standard varieties were heavily infected while the strains proved resistant. The yields, on the whole, were not as high as in 1929, a fact which may be partially accounted for by the shortness of the growing season in 1930, and the differences in soil productivity at Morden and Winnipeg. The data on some of the best yielding resistant strains together with a few of the standard varieties are given in table 32.

TABLE 32.—*Data on 9 of the highest yielding rust resistant strains of a Heigira Strain × Banner cross together with 4 standard varieties, 1930.*

Varieties and Strains	Heading	% Rust	Strength of Straw	Height	Maturity	Yield in Bushels	% Hull
299	51	0	88	42	81	81	27
524	49	0	92	37	80	79	25
129	47	0	87	35	77	74	23
587	51	0	87	38	81	74	25
294	51	5	90	40	81	73	24
601	49	0	87	39	80	73	23
476	48	0	90	38	78	72	24
553	47	0	90	36	75	72	23
548	49	0	83	37	78	71	27
Heigira Strain	45	0	75	32	73	49	25
Banner	52	87	83	38	79	22	43
Star	52	83	78	38	76	19	46
Victory	53	85	78	39	79	24	54

The data in table 32 show that some high yielding strains of oats resistant to forms 1, 2, 3, 5 and 7, forms which comprise about 98 per cent of all isolations made in Canada, have been produced. These strains, apart from being resistant, possess good strength of straw, are tall, medium early and comparatively low in percentage of hull.

Heigira Strain × Joanette Strain. From this cross, rod row data have been obtained on 7 strains showing resistance to forms 1, 2, 3, 4, 5 and 7. The data are shown in table 33.

TABLE 33.—*Data on 7 strains of a Heigira Strain × Joanette Strain cross, showing resistance to forms 1, 2, 3, 5 and 7 in the field and to form 4 in the greenhouse, together with the two parental varieties.*

Strains and Varieties	Heading	% Rust	Strength of Straw	Height	Maturity	Yield in Bushels	% Hull
18	47	5	88	39	84	71	25
34	52	5	88	39	88	61	28
14	47	5	82	38	88	58	23
17	47	5	85	41	90	58	34
12	48	5	88	38	88	57	26
37	53	5	87	42	89	55	32
115	54	5	88	38	89	55	29
Heigira Strain	45	5	77	34	73	60	25
Joanette Strain	54	85	68	36	85	27	35

The data in table 33 show that the strains resistant to the six forms, 1, 2, 3, 4, 5 and 7, have been produced. These strains, however, do not show as high resistance as those of the Heigira Strain × Banner cross. This

may be accounted for by the fact that they are comparatively later in maturing as is evidenced by the data in the table. The yields are not high but this is not surprising as neither parent is a particularly high yielder. The important feature concerning these strains is that they are resistant to forms 1, 2, 3, 4, 5 and 7, and will be valuable in crossing with some of the higher yielding lines of the Heigira Strain × Banner cross.

MISCELLANEOUS CORRELATIONS

In the F_4 and F_5 of a Heigira Strain × Banner cross, grown in rod rows, the degree of association between the measurable characters, heading, maturity, strength of straw, height and yield was studied. The results are given in table 34.

TABLE 34.—*Correlations between measurable characters in F_4 and F_5 of a Heigira Strain × Banner cross.*

Plant Characters	Correlation Coefficients	
	1929	1930
Heading—Maturity	.74 ± .03	.54 ± .05
Heading—Strength of Straw	.30 ± .05	.18 ± .05
Heading—Height	–.09 ± .07	.44 ± .06
Height—Strength of Straw	–.14 ± .07	.06 ± .07
Maturity—Strength of Straw	.27 ± .03	–.26 ± .02
Maturity—Height	–.19 ± .07	.66 ± .04
Yield—Maturity	.18 ± .07	.09 ± .07
Yield—Heading	–.08 ± .07	–.06 ± .05
Yield—Strength of Straw	.05 ± .07	.17 ± .07
Yield—Height	.10 ± .07	.37 ± .06

The data in table 34 show that the degree of association between the different measurable characters varies with season. Date of heading and days to maturity are fairly closely associated but were more so in 1929. Date of heading and days to maturity were associated with height in 1930 but showed no such association in 1929. Yield was found to be somewhat associated with height in 1930.

DISCUSSION

The problem of breeding for resistance to stem rust and smut in oats has been studied by a number of investigators. Strains resistant to rust and resistant to smut have been produced, but none of them possess particularly high yielding ability. That is to say, when grown during a season in which little disease is present these strains do not give as high yields as the ordinary high yielding commercial varieties. Therefore, from the practical standpoint, a great deal has yet to be accomplished.

The existence of physiologic specialization greatly complicates the problem. In *Puccinia graminis avenae* there are eight known forms, therefore, in order to have complete resistance to stem rust, resistance to all forms must be obtained. At the present time this appears impossible, as no varieties have as yet been found which are resistant to form 6. To the other forms, however, there is sufficient varietal resistance to build up synthetically resistance to all of them. Such resistance is sufficient for the

present, as form 6 has been found only on rare occasions in Canada. However, there is no guarantee that this form or other such virulent ones will not become prevalent in the future. If this situation arises and no resistance in the meantime has been obtained to forms as virulent as 6, the production of resistant varieties will be an impossibility.

All investigators, with the exception of Dietz (*6*) in his studies with three genetically different strains of the Burt oat, agree that resistance to oat stem rust is dominant and governed by a single factor. No one, however, previous to the results presented in this paper, except Waterhouse (*48a*) has studied the inheritance of the mode of reaction to specific physiologic forms of *Puccinia graminis avenae*. The results obtained show fairly conclusively that in the crosses studied, the reactions of forms 1, 2, 3, 4 and 5 are governed by a single factor, and that the reactions of forms 1, 2, 3 and 5 are controlled by the same factor—a fact which greatly simplifies the problem of breeding for stem rust resistance.

Physiologic specialization also exists within the smut fungi. Reed (*38*) made a fairly extensive study of physiologic specialization in smut by inoculating varieties with smut inoculum from various sources. This writer found that varieties resistant to smut from one source were susceptible to inoculum from other sources, and that some varieties were resistant to smut inoculum from all sources.

Studies of reaction to smut in oats have demonstrated that immunity, resistance and susceptibility are inherited characters, and that strains resistant to both smuts can be produced. The results obtained in this investigation are in accordance with previous findings. As smut reaction is not completely expressed in the progeny, it is difficult to determine the nature and number of the factors involved in smut inheritance. However, in previous studies on the inheritance of smut reaction some investigators have assumed that a single factor hypothesis explained the results obtained, while others suggested two and three factor differences.

In the studies on the inheritance of smut reaction in a Victory × (Minota-White Russian × Black Mesdag) cross, there was evidence of transgressive segregation in families inoculated with loose and covered smuts. This result indicates that two factors at least, govern the inheritance of smut reaction in this cross. No detailed genetic analysis has been made as one generation only has been studied. It is assumed, however, that the Victory × (Minota-White Russian × Black Mesdag) parent carries a factor for susceptibility as well as one for resistance, and that the Victory parent carries a factor which prevents complete susceptibility. The genetic constitution of the two parents is, therefore, AAbb and aaBB respectively. Garber, Giddings and Hoover (*14*) also obtained transgressive segregation in a cross between Gopher, which is semi-resistant, and Black Mesdag, which is resistant. These writers, however, used composite samples of smut inoculum and did not differentiate between loose and covered smut.

As a correlation coefficient of .683 ± .021 was obtained between the infection capabilities of the physiologic strains of loose and covered smut,

it would suggest that in the cross studied, both species of smut are similar in virulence.

It is the general opinion that the rust fungus thrives best on healthy plants. In an experiment to determine what effect smut infection had on rust development, it was found that the presence of smut on a rust resistant variety caused a decrease in its power of resistance. Dillon Weston *(6a)* obtained a similar result with wheat. This writer studied the effect of bunt infection of the host on the development of *Puccinia glumarum* Erikss. and Henn. and found that in general there was an increase in susceptibility of varieties to yellow rust when infected with bunt.

The studies on the inheritance of lemma colour in a yellow-white cross, Heigira Strain × Banner, the latter being the white parent, indicate that white is dominant to yellow. The F_2 data suggest that a single factor is operative, but as the number of individuals studied was small, 71, the results cannot be considered as indicative. The breeding behaviour in F_3 indicates that two factors govern the inheritance of colour in this cross. In another yellow-white cross, Richland × (Minota-White Russian × Black Mesdag), in which Richland is the yellow parent, the F_2 data suggest that yellow is dominant to white, and governed by two factors. The breeding behaviour in F_3, however, indicates that there is a single factor difference between the two parents for colour of glume.

Nilsson-Ehle *(26)* in previous studies obtained monogenic differences between yellow and white hulled oat varieties, and according to Hayes and Garber *(18a)* results of crosses show that yellow is dominant over white, or partially so.

In a cross between black and white varieties, Joanette Strain × (Minota-White Russian × Black Mesdag), in which Joanette Strain is the black parent, the segregation for colour in the F_2 indicated a 12:3:1 ratio of black, gray and white. Joanette Strain apparently carries two dominant factors, one for black and one for gray, black being epistatic to gray. In another cross between a yellow variety and Joanette Strain, gray coloured grains also appeared, a result which substantiates the hypothesis that Joanette Strain carries a factor for gray. A similar ratio was obtained by Nilsson-Ehle in a cross between black and white oat varieties. Ratios of 15 black: 1 white and 3 black: 1 white, have also been obtained.

In a black-yellow cross, Monarch Strain × Heigira Strain, a ratio in F_2 of 12 black: 3 white: 1 yellow was obtained. Monarch Strain is assumed to carry a factor for white as well as black. This ratio is not in agreement with results obtained by previous investigators. Nilsson-Ehle *(26)* in a cross between black and yellow varieties obtained a ratio of 12 black: 3 yellow: 1 white. In another yellow-black cross the same writer obtained in F_2, black, yellow, gray and white segregates. Surface *(45)* and Love and Craig *(21)* in crosses between a black *fatua* and yellow *sativa* obtained a digenic segregation of 12 black: 3 gray: 1 white.

The ultimate aim in the rust and smut studies is to produce high yielding, disease resistant oat varieties. Of the several crosses studied, yields on rust resistant lines of the Heigira Strain × Banner and Heigira

Strain × Joanette strain crosses, only, were obtained. A total of 87 F_3 resistant lines, of the Heigira Strain × Banner cross, were placed in a rod row test during the summer of 1929, and of this number, under conditions in which no rust epidemic was present, six possessed higher yielding ability than the Banner parent. Banner yielded 80 bushels per acre and Heigira Strain 65. The following year, 66 of these resistant lines were grown and subjected to an artificial rust epidemic in which forms, 1, 2, 3, 5 and 7 were present. All of these strains were free from rust, while the standard varieties were heavily infected.

During the summer of 1930 twenty-one lines of Heigira Strain × Joanette Strain cross, resistant to forms 1, 2, 3, 4, 5 and 7, were grown in a rod row test. These were not particularly productive, which was to be expected, as neither of the parents were outstanding in this respect. The principal feature, however, concerning these lines is that they possess resistance to form 4 as well as to the other five forms and will be valuable for breeding purposes.

Summary

1. The problem of breeding for resistance to all forms of stem rust, at the present time, is difficult owing to the existence of form 6.
2. There is sufficient varietal resistance to all other known forms, and resistance to them can be built up synthetically.
3. Rust reaction both in the field and in the greenhouse is governed by a single factor, and resistance in both cases is apparently dominant.
4. No relationship was found to exist between rust reaction and such characters as maturity and colour of lemma.
5. The rust reactions of forms 1, 2, 3, 5 and 7 in the two crosses, Heigira Strain × Banner and Heigira Strain × Joanette Strain are controlled by the same single genetic factor.
6. The rust reaction of form 4 in the Heigira Strain × Joanette Strain cross was apparently controlled by two factors, while in the cross Joanette Strain × (Minota-White Russian × Black Mesdag) by a single factor.
7. Fairly high yielding oat strains resistant to the prevalent forms of oat stem rust have been produced.
8. Oat strains resistant to both types of smut can be produced without much difficulty.
9. Transgressive segregation took place in lines inoculated with both loose and covered smut.
10. A fairly high correlation existed between the amount of infection in lines inoculated with both loose and covered smut.
11. Smut infected plants are more subject to rust infection than non-smutted ones.
12. In two crosses between yellow and white grained varieties, digenic and monogenic differences were obtained. White was dominant to yellow in one cross and apparently recessive in the other.

13. In crosses between black and yellow and black and white grained varieties, black was dominant, and in both cases digenic differences were obtained.
14. The degree of association between such measurable characters as date of heading, days to maturity, height, etc., varies with season.
15. The association between date of heading and days to maturity is fairly constant from year to year. Both of these characters were associated with height in 1930, but showed no such association in 1929.
16. Yield was found to be slightly associated with height in 1930.

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LE ROLE DES RAYONS ULTRA-VIOLETS DANS L'ALIMENTATION DES ANIMAUX DOMESTIQUES.

M. Frateur, professeur à l'Université de Louvain, en Belgique, a récemment publié dans "Onze Ploeg" l'étude suivante.

Les conceptions concernant les nécessités alimentaires de nos animaux domestiques ont subi, dans ces dernières années, plus d'une modification. Le nombre de ceux qui croient qu'une ration est parfaite lorsqu'elle satisfait aux besoins de l'organisme animal en albumine, hydrates de carbone et graisses, diminue de jour en jour. L'alimentation rationnelle se trouvait, dans le dernier demi siècle, presque complètement sous les directives des chimistes. Ceux-ci considéraient comme indispensable pour l'alimentation uniquement ce qu'ils parvenaient à déterminer dans les aliments par analyse chimique. Et comme ils trouvaient par les méthodes ordinaires d'analyse, en ordre principal des matières albuminoïdes, des hydrates de carbone et des graisses, à coté d'une petite quantité de matières minérales, leurs conclusions naturelles furent que ces produits seuls avaient de l'importance pour l'alimentation du bétail. Il y avait cependant déjà eu des savants qui constatèrent que des rations, composées suivant les règles en vigueur, ne donnaient cependant pas de résultats avantageux, et qu'il devait donc y avoir autre chose en jeu. Ils proposèrent de déterminer la valeur réelle des rations, composées d'après les données chimiques, par les résultats réels obtenus avec les animaux. C'étaient les précurseurs des méthodes biologiques actuellement en vigueur. Par celles-ci on fait l'analyse d'un aliment par l'animal vivant; d'ailleurs l'analyse du sol par les plantes est appliquée depuis longtemps. Les méthodes scandinaves, des unités fourragères, et le coefficient de transformation des aliments d'après nos conceptions, appartiennent d'ailleurs à ce groupe de méthodes. En réalité on examine par ces méthodes quelles influences des aliments ou des rations déterminées ont sur les manifestations physiologiques de l'animal. En d'autres mots, c'est le résultat final constaté sur l'animal qui nous renseigne sur la valeur réelle d'une substance alimentaire ou d'une ration. Cela ne veut pas dire que dans la composition d'une ration il faille négliger les anciennes données chimiques; mais elles sont vérifiées par les résultats réels obtenus chez les animaux. A ces méthodes nous devons déjà plusieurs faits nouveaux, notamment l'existance et le rôle de ces substances spéciales que l'on appelle Vitamines et dans la connaissance desquelles la chimie n'a pas encore pu pénétrer, ainsi que l'échange très complexe de combinaisons minérales spécifiques auxquelles plusieurs savants consacraient également leur temps. Par ces méthodes on a pu aussi déterminer l'action de certains rayons—par exemple les rayons ultra violets—sur le métabolisme ou les transformations des matières dans l'organisme. On a pu ainsi déterminer que c'est la vitamine anti-rachitique D qui intervient probablement en ordre principal dans tout le processus de transformations minérales dans le corps. Elle se trouve en relations très étroites avec les rayons ultra-violets, de telle façon que sans ces rayons ces transformations s'opèrent très mal ou même proba-

blement pas du tout. Ces rayons peuvent provenir de différentes sources, mais la source de ces rayons n'a à ce point de vue aucune importance.

Ils peuvent provenir du soleil qui en dégage, comme on le sait, de très grandes quantités, quoique cependant une minime quantité seulement arrive sur notre globe, principalement en hiver et dans les régions du Nord. Mais on a heureusement en dehors du soleil encore d'autres sources de rayons ultra-violets, notamment dans les émanations électriques. En médecine, ces sources sont déjà appliquées régulièrement pour des états alimentaires anormaux. Les résultats ainsi obtenus dans le traitement d'enfants rachitiques sont suffisamment connus, et ces résultats sont aussi bons que ceux que l'on obtient par des bains de soleil. Ils ont sur ceux-ci le grand avantage que la dose des rayons peut être réglée et facilement concentrée sur certaines régions du corps.

D'autres recherches, notamment celles du Dr. A. F. Hess de Columbia University, le Prof. Harry Steenbock de l'Université de Wisconsin, ainsi que celles de A. Windaus en Allemagne (1) ont fait ressortir que certaines substances alimentaires, lorsqu'elles étaient irradiées avec des rayons U. V. recevaient et conservaient des propriétés analogues à celles de la vitamine D. Quand on administrait ces aliments irradiés à des animaux, on obtenait le même résultat que par irradiation directe. Cette découverte a une très grande importance pratique. De cette façon il devient possible de faire pénétrer partout les rayons ultra-violets spécifiques, même là où aucun rayon de soleil ni un courant éléctrique ne peut pénétrer. Pour juger de l'importance de ces découvertes, on n'a qu'à songer un instant aux millions de francs de pertes occasionnées dans l'exploitation de nos animaux domestiques par le défaut de rayons ultra-violets avec ses conséquences de maladies, dépérissements, mauvais résultats dans l'exploitation, etc. C'est probablement la cause principale du mauvais état alimentaire dans lequel se trouvent nos animaux domestiques, après les longs mois d'alimentation d'hiver à l'étable, et cela nonobstant que les animaux ont été bien nourris suivant les anciennes données de l'alimentation rationnelle. L'accroissement de la production laitière produit par le pâturage du printemps, chez du bétail cependant bien nourri trouve là probablement aussi sa cause principale. La jeune herbe est irradiée par le soleil du printemps qui est très riche en rayons U. V. et qui produit ainsi dans les plantes de fortes quantités de Vit. D.

Mais on ne dispose pas toujours d'herbe printannière, ni de soleil. Nos animaux domestiques, même là où il y a beaucoup de pâturages, restent quand même une grande partie de l'année à l'étable, principalement pendant les mois d'hiver. D'autre part, les animaux qui sont engraissés, tels que les veaux à l'engrais, les porcs, les boeufs, etc., ne sortent pratiquement pas de l'étable. On a d'ailleurs tout avantage à les conserver dans des locaux sombres. Il en résulte que ces animaux ne peuvent obtenir la quantité indispensable de Vit. D. que par les aliments qui leur sont donnés. Et c'est là une des causes principales des accidents nombreux qui se produisent lors d'une alimentation exclusive à l'étable. Par une application méthodique des sources de Vit. D. on pourra certes arriver à diminuer le pourcentage de la mortalité. Dans la Réassurance contre la

mortalité du bétail du Brabant, un tiers environ des accidents peuvent être rattachés à une insuffisance de vitamine D.

Les découvertes des savants précités nous ouvrent d'autre part de nouveaux horizons dans l'exploitation animale. Je veux me borner ici à un exemple. Des éleveurs de petit bétail progressistes essaient depuis longtemps d'exploiter des animaux sur petits parcours. A l'Institut de Zootechnie plusieurs essais ont déjà été faits dans ce sens. Mais sans parcours à l'air libre les animaux souffrent de déficience alimentaire qui met l'exploitation en déficit. Ce système présente néanmoins de très grands avantages. C'est le seul qui permettra une exploitation industrielle vraiment méthodique. L'administration d'aliments irradiés sera probablement un grand facteur dans la suppression du parcours à l'air libre.

Dans leurs premières recherches, Hess et Steenbock crurent qu'il devait y avoir une substance spéciale qui était irradiée par les U. V. Il en est bien ainsi. Cette substance a été déterminée depuis peu par une série de recherches. On a cru d'abord que cette substance était le Cholesterol. Mais Hess en Amérique, Windaus en Allemagne, Rosenheim et Webster en Angleterre, trouvaient que cette substance n'était pas le Cholesterol. C'est l'Ergosterol qui irradié peut être introduit dans les rations comme source de vitamines D. Le grand avantage de cette substance, c'est que son activité, comme source de vitamine D. peut être reglée avec précision. Et cela est une question essentielle. En effet, si la quantité employée est trop forte, on a des résultats néfastes. Le métabolisme des sels minéraux est alors de nouveau dérangé, et d'après des expériences récentes, j'ai tout lieu de croire que sur des jeunes sujets des accidents mortels peuvent se produire. Pour prévenir ces effets néfastes, et en même temps pour empêcher les falsifications, Steenbock d'une part et Windaus d'autre part, ont pris un brevet mondial pour l'irradiation des aliments. Ce brevet est pris en faveur des institutions scientifiques dans lesquelles ces deux savants travaillent, de façon à pouvoir promouvoir de nouvelles recherches dans ce domaine. C'est la Compagnie du brevet qui exerce le contrôle sur les firmes qui ont obtenu l'autorisation d'appliquer l'irradiation, et qui règle l'emploi de l'Egosterol irradié. Quand on considère d'une part les grandes dépenses nécessitées par un laboratoire de recherches sérieux, et d'autre part la situation matérielle des savants qui ont pris comme carrière la recherche scientifique pure, on peut très bien comprendre ce procédé. Le grand savant Branly a trouvé les ondes sur lesquelles reposent toutes les communications sans fil, et il n'a toujours qu'un misérable laboratoire à l'Institut Catholique de Paris. Quoique âgé il est obligé de retourner tous les jours à son home à pied et par métro ! Mais Marconi qui fit breveter des appareils à ces ondes, est sénateur, a son propre Yacht, se repose en mer pour pouvoir étonner le monde avec des nouvelles inventions pratiques, sources de nouvelles sociétés.

Steenbock et Windaus ont jugé avec raison que les avantages matériels de leurs découvertes revenaient à leurs Institutions scientifiques. C'est ce qui a d'ailleurs été fait après la découverte de l'Insuline dans le pancréas, la substance qui permet actuellement de combattre avec succès le diabète. Ne serait-il pas désirable que chez nous également une association puisse

se créer pour exploiter les découvertes de nos savants et soutenir ainsi nos institutions scientifiques ?

L'activité anti-rachitique de certaines substances alimentaires est connue depuis longtemps. On sait que l'huile de foie de morue a des propriétés curatives dans certains cas, ainsi que des propriétés préventives. On sait cependant aussi que dans le traitement du rachitisme avec l'huile de foie de morue on n'obtient des résultats réels qu'en complétant le traitement avec des irradiations solaires ou des irradiations aux rayons U.V. D'autre part on a trouvé que l'huile de foie de morue de sources différentes peut avoir une valeur très inégale, et que l'huile brute non purifiée a la plus grande activité. D'autres recherches ont fait ressortir que l'huile de foie de morue peut jouer un rôle très important dans le métabolisme des matières minérales, et cela par la présence de vitamines, notamment de V. D. Et cela explique comment cette substance a pu donner des résultats dans la prévention et le traitement du rachitisme, alors qu'elle n'a pas une teneur spécifique en chaux et en phosphore, et que cependant l'administration directe de composés calciques et phosphorés ne donnait pas de résultats, et dans certains cas même empirait la situation. Mais ici se pose la question: où est-ce que l'huile de foie de morue, qui n'est au fond qu'une matière grasse, cherche ces propriétés spécifiques ? Celles-ci proviennent de la présence d'une assez forte quantité de Vit. D. qui forme le noyau des transformations minérales dans l'organisme. Comme source de ces vitamines naturelles on ne peut logiquement indiquer que le soleil. Celui-ci irradie l'eau et ses rayons U. V. pénètrent jusque dans tous les êtres qui y vivent. On peut ainsi très bien comprendre que cette irradiation doit varier considérablement suivant la situation des eaux. Et là réside surtout la cause principale des grandes différences que l'on constate dans l'huile de foie de morue d'origines différentes.

Cependant quand on pousse plus loin ces recherches sur l'origine de la vitamine D. dans l'huile de foie de morue et les substances analogues, on peut trouver différentes voies par lesquelles la Vit. d'irradiation peut pénétrer dans le foie. On a tout d'abord le chemin le plus court, à savoir l'irradiation directe de la peau des mammifères aquatiques et des poissons qui fournissent l'huile de foie. Mais on ne voit pas très bien pourquoi le foie de ces animaux est plus riche en Vit. D. que celui d'animaux qui vivent sur terre ferme, et qui se baignent aussi directement dans le soleil. Une seconde voie ce sont les myriades de petits êtres—plankton, protozoaires, etc.—dont vivent les poissons et les mammifères aquatiques. Il n'est pas impossible que ces petites êtres soient plus riches en substances irradiables et forment ainsi une source importante de Vit. D. pour leurs destructeurs. Et enfin on a toutes les plantes aquatiques et les algues qui servent d'aliments à de multiples espèces de poissons et de mammifères aquatiques.

Il paraît bien probable que c'est par voie indirecte que l'huile de foie de morue gagne sa richesse en Vit. D. L'animal consomme des aliments riches en Vit. D. et celle-ci est retenue dans le foie, ce qui arrive d'ailleurs régulièrement pour toute substance qui pourrait occasionner des dérangements si elle était introduite dans de trop fortes quantités dans le sang. C'est le cas notamment avec la Vit. D. L'organisme n'a

qu'un besoin très limité de cette substance. Si la quantité devient trop petite ou trop forte, il y a des dérangements dans les transformations des matières. Ces Vit. D. peuvent pénétrer dans l'organisme par deux voies, à savoir, directement par la peau lors d'une irradiation, et indirectement par les intestins avec les aliments. Quand la peau reçoit des quantités excessives des rayons U. V. elle réagit et se protège d'une part par l'épaississement de l'épiderme, et d'autre part par la production de dépôts colorés dans les cellules profondes. De cette façon, les rayons peuvent pénétrer moins facilement jusque dans le derme pour s'y combiner avec les matières de la série des stérols. Il se forme donc un écran dans l'épiderme. Si cet écran n'existe pas, une irradiation intense peut avoir des conséquences néfastes, dont le coup de soleil est l'exemple le plus typique. Par les aliments il peut aussi arriver dans l'intestin un excédent de Vit. D. Mais ici se trouve le contrôle sévère du foie qui arrête tout l'excédent. On peut d'ailleurs très bien comprendre qu'en règle générale il n'y a pas ici de grands excédents de Vit. absorbés puisque les aliments naturels se défendent eux-mêmes contre une absorption trop forte. S'il arrive que le foie ne peut pas retenir l'excédent de Vit. D. il se produit des dérangements dangereux. Le danger réside donc uniquement dans une irradiation trop forte de la peau aussi bien par irradiation naturelle que par irradiation artificielle et dans l'administration d'aliments artificiellement trop enrichis en Vit. D. Il est nécessaire pour cela d'appliquer l'irradiation artificielle avec une grande prudence, aussi bien pour l'irradiation directe que pour l'irradiation indirecte. Les accidents nombreux qu'on a déjà observés aussi bien dans les laboratoires que dans la pratique sont là pour prémunir contre un emploi inconsidéré d'irradiation aussi bien des animaux que des aliments.

La façon d'agir des rayons U. V. dans l'organisme vivant se produit d'une façon spéciale. Ces rayons donnent à des substances déterminées de la série des stérols appartenant au groupe des alcools supérieurs la propriété de jouer un rôle dans le métabolisme. Les premiers chercheurs ont cru que c'était le Cholestérol chez les animaux, et le phytostérol chez les plantes, qui étaient influencés. Mais les dernières recherches de Hess et de Windaus ont démontré que ce ne sont pas ces substances, mais bien d'autres, des stérols très voisins mais avec des chainons carbones non saturés. Si on sature ces stérols par exemple avec de l'hydrogène, l'irradiation n'a pas d'effet. Parmi ces stérols c'est l'Ergostérol qui semble jouer le rôle principal. Cette substance se trouve en grande quantité dans l'ergot de seigle, un champignon qui se développe, comme on sait, sur le seigle. On la trouve aussi dans les levures et ce sont celles-ci que l'on emploie actuellement pour la production de l'Ergostérol destiné à l'irradiation. Par elle-même cette substance n'est pas active comme Vit. D.; elle le devient seulement sous l'influence des rayons U. V. Son activité est très grande, beaucoup plus grande que la plupart des sources de Vit. D. que l'on connait actuellement. Elle est active pour la calcification des os dans une dose indéfini-décimale, par exemple 0.002 mg. par jour. Et son action est des milliers de fois plus grande que la meilleure huile de foie de morue. Il y a d'autre part une relation étroite entre l'activité de l'Ergostérol irradié et celle de certaines glandes endocrines. Ces glandes

jettent dans le courant circulatoire des substances qui règlent le métabolisme de l'organisme. Les glandes parathyroïdes qui se trouvent à côté des glandes thyroïdes dans le cou, sont probablement en relations étroites avec les Vit. D. On donne à des singes une nourriture unilatérale de façon à provoquer une déficience en matières minérales. Après administration d'Ergostérols irradiés, l'animal redevient normal. On enlève ensuite les glandes parathyroïdes et après quelque temps les manifestations dues à une déficience de matières minérales apparaissent à nouveau.

De tout ce qui précède, il résulte suffisamment clairement que l'administration d'Ergostérols irradiés peut produire beaucoup de bien, principalement dans l'exploitation de nos animaux domestiques. Les conditions économiques nous obligent en effet souvent à élever et à exploiter nos animaux dans des conditions qui sont loin d'être physiologiques. Il ne faut cependant pas croire qu'il suffiira dorénavant de donner une cuillerée à café de rayons U. V. aux animaux, pour qu'ils soient bien portants, et pour que nous gagnions de l'argent en les exploitant. Non, maintenant aussi bien que jadis, ce sera l'oeil du maître qui engraissera le cheval. Mais on peut voir clair actuellement là où il faisait encore noir.

C. S. T. A. Changes Mailing Address

It has been decided to discontinue the use of a post office box for the C.S.T.A. as mail delivery direct to the office is more convenient. From now on all correspondence should be addressed to:

Canadian Society of Technical Agriculturists,
306 Victoria Building,
Ottawa, Ont.

CURRENT PUBLICATIONS

27. The Profitableness of Farming in Scotland. Dr. J. S. King. Department of Agriculture, Scotland.

This is a "Report on the financial results obtained on certain groups of farms in Scotland in 1928-29 with statistical account of the farms in the Counties of Berwick, Roxburgh and Selkirk."

The financial returns include costs of production and "hints as to the more economical forms of farm management under present conditions, even without any detailed apportionment of costs among the various departments of the business." J.C.

28. Value of Family Living on Iowa Farms. Elizabeth Ellis Hoyt and Ethel C. Morgan. Agricultural Experimental Station, Iowa State College of Agriculture and Mechanic Arts, Bulletin No. 281.

This bulletin is based upon a study of 147 Iowa farm families who kept accounts for one year. The value of the living averaged $1,624.95; this amount of course included food, fuel and shelter furnished by the farm. The farm actually furnished 42.6 per cent of the value of the living of all farms. The food cost was $640.86 (39.4%), over three fifths of this amount was furnished by the farms. The average expenditure for clothing was $153.87 or 9.5 per cent of the total. Housing was valued at $267.12, fuel and light at $100.25; sundries amounted to $462.85 or 28.5 per cent of the total. "The most conspicuous ambitions of these farm families were to increase their property and income and to educate their children."

J. C.

29. Soil Organic Matter as a Factor in the Fertility of Apple Orchards. Bulletin 261. Pennsylvania State College, January 1931. R. D. Anthony.

Observations in a State College apple orchard lead the author to the belief that any system of orchard management eventually influences yield mainly to the extent that it modifies the organic content of the soil. Satisfactory tree growth and yields of fruit were directly correlated with a sufficient supply of organic matter, due to its favorable influence on moisture and fertility conditions.

Fertilizers were of value not only as a direct supply of plant food to the trees, but also indirectly in stimulating the growth of the grass or green manuring crops which added to the organic content of the soil. Further the growth of these crops is shown to be a fairly reliable index to probable tree growth and yields eight to ten years later. Where green crop growth is heaviest, there will later be reflected a corresponding increase in tree growth and yield. The grass or green manure crop growth therefore may be used as a means of estimating the future value of any system of orchard management. Cultivation without green manure crop quickly resulted in unprofitable trees through depletion of the organic matter of the soil.

Soils high in organic matter were able to produce larger amounts of nitrates and take up larger amounts of water than those with low organic content. Consequently in dry summers the soil high in organic content not only was able to carry the crop of fruit better but also produced good cover crops. On soils that are well adapted for grass, the organic content and therefore soil fertility probably may be maintained or built up in the mature apple orchard by the use of sod rotations, perhaps better than by the use of annual green manure crops. E.F.P.

30. The Farm Business in Saskatchewan—Survey of the Swift Current-Gull Lake District by William Allen, Department of Farm Management of the University of Saskatchewan.

This report has recently been published as Agricultural Extension Bulletin No. 52 of the University of Saskatchewan and is the fourth of a series of studies of farm businesses in areas representative of the major types of Saskatchewan agriculture. The farmers were visited by representatives of the University in the summer of 1928. Ninety-six farmers specializing in wheat production cooperated in supplying complete information concerning their farm operations and finances for the 1927-1928 crop year. The report, which is quite comprehensive, includes a brief description of the area, general farm management data,

studies of farm efficiency, costs of production analysis, studies of farmers' progress and indebtedness, together with numerous sociological notes. Thirty-four replies to a supplementary questionnaire sent to these farmers in December, 1930, made it possible to report data on the receipts from the crops grown in 1928, 1929 and 1930, and also to note some of the recent significant changes in the farm practices of the district.

This bulletin is now available for distribution, requests for which should be sent to the Director of Extension of the University of Saskatchewan at Saskatoon.

Earlier farm management surveys are reported in Bulletin No. 37, Grain Farming on the Prairie—The Belbeck District, 1925-1926 Crop Year; Bulletin No. 43. Farming in the Park Belt—The Melfort District, 1925-1926 Crop Year; and Bulletin No. 46, Farming in South-Eastern Saskatchewan—the Alameda District, 1926-1927 Crop Year. J.G.R.

31. Public Speaking for Executives. Charles W. Mears. Published by Harper and Brothers, Price $3.00.

As the librarian handed this book out to be reviewed she remarked, 'I don't know that the agricultural men need it; they seem to be such good speakers, at least any I have ever heard'. Perhaps they are better than the average; if so it is due to the hours of English and Public Speaking included in the B.S.A. courses and to those hilarious evenings spent under the auspices of the local Debating Society. With training in this art now a part of School Fair and Junior Farmer programmes we may expect a race of super-speakers in a few years. In the meantime most of us could profitably spend an hour or two taking notes from this book by Mr. Mears. Any one who has any intention of acting as chairman of a meeting should be compelled to take Chapter XII on 'The Meeting and the Chairman' and learn it by heart. 'Public Speaking for Executives' may be secured on loan from the Dominion Department of Agriculture Library, Ottawa.

32. Beans. T. F. Ritchie. Dominion Department of Agriculture Bulletin No. 153—New Series. Available from the Director of Publicity, Ottawa.

With the idea of a fixed type for each variety of garden bean there has arisen a need for a type book dealing with the technical description of each of the twenty-five varieties decided upon as the most outstanding by the Vegetable Committee under the Canadian Seed Growers' Association. This bulletin is intended to serve as a guide to seed growers. It is hoped that it will be the means of establishing a fixed type for each variety for present and future seed production. The descriptive work has been done in the Horticultural Division of the Central Experimental Farm, Ottawa, in co-operation with the Canadian Seed Growers' Association and the Seed Branch of the Department of Agriculture. Types have been photographed on a background of cross-section paper and seed types are very well shown in two coloured plates by Faith Fyles.

33. Major Forces in World Depression. Published by the National Industrial Conference Board, Inc., 247 Park Avenue, New York. Price $1.50.

This publication gives a condensed analysis of the factors entering into the present business depression. To quote from the preface, 'Many forces have operated to produce the world-wide business depression. From country to country the character and severity of the depression have been modified by such factors as geographical location, natural resources, character and size of population, social and political conditions, tariffs and subsidies, relations with foreign countries and similar circumstances'. A table is given showing the factors which are most important in producing the depression in each of thirty countries. It is interesting to note the following comment regarding Canadian conditions: 'Canada has not indulged in excessive borrowing and has no special financial difficulties. The soundness of the financial structure and the absence of political difficulties account for the relatively favourable economic situation of the country. Canada, however, has been unfavourably affected by the decline in the prices of foodstuffs and raw materials and by poor harvests in 1929 and 1931. Although Canada has well developed manufacturing industries the producing power of the country is provided mainly by the population that is engaged in agricultural pursuits'.

In summarizing the forces at work it is stated that 'the fundamental difficulty of the world at the present time seems to lie in the existence of excess productive capacity in many countries, side by side with the existence of large areas thickly populated and

rich in natural resources, the people of which have a low standard of living and are producing little and consuming little. The opening up of these areas to world trade is impeded mainly by the political and social unrest which makes the development of orderly economic life impossible'.

Those who desire to secure a bird's-eye view of the present situation will find this book exceedingly valuable.

34. THE WORLD'S ECONOMIC DILEMMA. Ernest Minor Patterson. Published by McGraw-Hill Book Company, Price $3.50.

The publishers of this book make the following comments: 'We live in a day of universal economic interdependence. Every part of the world now depends on every other part, and complete international co-operation in business is both desirable and necessary. Yet, because of the existence of numerous separate states with their conflicting political interests, the free movement of people and of goods is checked. This, in brief, is the economic dilemma which confronts all peoples: How can a world economically unified but politically divided successfully carry on the business of making a living? In discussing the problem, Professor Patterson (Head of the Economics Department, University of Pennsylvania) reviews the economic developments of the Twentieth Century, treating of the effects of population growth and pressure, the unequal distribution of natural resources, the changing structure of business and finance as vital factors in the situation. He lays particular stress upon the influence of large scale production, the gold standard, the modern struggle for markets, the growth of corporations and of investments in relation to international affairs. He examines the present economic status of Great Britain, France, Germany, Italy, Japan and the United States, and touches upon the relations of these nations to one another'.

In the final chapter entitled 'Solving the Dilemma', Professor Patterson names four agencies of constructive effort. The first of these is the system of commercial treaties, including mutual concessions between nations; second, the form of international co-operation found in the trust or cartel, through which huge industries settle their differences with little appeal for political interference. He names the International Chamber of Commerce as the third factor through which economic problems are studied and a better understanding reached between business men of various countries. Finally he pays tribute to the work of the economic section of the League of Nations, and states that 'for economic ill-will and friction it is gradually helping us to substitute sanity and a spirit of adjustment'. He concludes by stating that 'it is in these four ways, but not only in these four ways, that the world is working its way out of a dilemma that might easily become an *impasse*. Though the gains are at times slow there is ample reason for believing that progress is really being made'.

35. THE USE OF ARTIFICIAL ILLUMINATION FOR GRADING GRAIN. D. C. Rose. Canadian Journal of Research, Vol. V., No. 1, July, 1931.

The first part of this paper is a description of artificial lighting units designed to give a suitable illumination for grading grain. Two types of illumination are being tried; first, the imitation of daylight by means of daylight lamps; second, the use of coloured lights which emphasize the bad and good points in wheat. A combination of a mercury lamp, neon lamp and the General Electric type S1 sun lamp gives promise of being a satisfactory source of illumination of the second type. A grain grading unit of each type is being given a prolonged trial.

The second part describes experiments which were an attempt to find a more objective means of grading wheat. The light reflected from wheat of different kinds and different grades was analyzed both spectroscopically and by means of a photo-electric cell and light filters. In the spectroscopic measurements ultra-violet light was included. The results indicate a certain amount of selective reflection but the variations with the different grades are not of a nature which would be helpful in grading wheat.

CONCERNING THE C.S.T.A.

REORGANIZATION OF COMMITTEE ON RESEARCH

At the last annual convention of the Society held at Guelph, the Nominations Committee recommended the tentative reappointment of the former Committee on Research, with the understanding that, if the Executive Committee saw fit to alter the existing method of appointment of members to this committee, they should have the power to do so.

In a discussion following the meeting the Executive Committee after exhaustive consideration, decided that the Committee on Research should consist in future of a Chairman elected "at large" by the Convention and of one member each elected by the various affiliated societies or groups. It was, accordingly, decided to retain the former chairman, who was empowered to get in touch with the officials of the various groups, with a view to forming a temporary committee, until such time as appointments could be ratified by the groups at their next meeting.

At the same time, the opinion was strongly expressed by some members of the Executive, that the general Committee on Research could perform a useful service by encouraging the formation of and keeping in close touch with the local sub-committees on Research. The annual report of the Committee would then include:

1. A general survey of research activities in Canada as indicated by the reports of such sub-committees forwarded directly to the Chairman not later than April 1st of each year.

2. A series of reports covering the activities of the different groups prepared by the member representing that group, also forwarded to the Chairman not later than April 1st of each year. These reports would consist as follows:

(a) A general summary of research accomplished in each particular field for the past year.

(b) An outline of the activities of the group for the past year.

(c) Recommendations or suggestions for the improvement or extension of the work in each particular field.

The present personnel of the Committee stands as follows:

Dr. W. H. Brittain, Macdonald College, Que.—Chairman.

Prof. J. G. Coulson, Macdonald College, Que.—Representing the Canadian Phytopathological Society.

Mr. M. B. Davis, Central Experimental Farm, Ottawa, Ont.—Representing Horticultural Group.

Prof. J. H. Ellis, Manitoba Agricultural College, Winnipeg, Man.—Representing Soils Group.

Mr. G. D. Matthews, Experimental Farm, Scott, Sask.—Representing Western Canadian Society of Agronomy.

Dr. J. E. Lattimer, Macdonald College, Que.—Representing Canadian Society of Agricultural Economics.

Mr. F. H. Reed, Experimental Station, Lacombe, Alta.—Representing Canadian Society of Animal Production.

Secretaries of local societies are requested to send to the General Secretary at the earliest possible moment the personnel of local sub-committees on Research.

C.S.T.A.—O.A.C. BANQUET AT ROYAL WINTER FAIR

The annual joint C.S.T.A.-O.A.C. Alumni banquet was held on Friday evening, November 20th, in the Elizabethan Room of the Royal York Hotel, Toronto. Arrangements were in the hands of the two executives headed by W. A. Weir, President of the Western Ontario Branch of the C.S.T.A. and W. H. J. Tisdale, President of the Ontario O.A.C. Alumni Association. About two hundred guests enjoyed a splendid programme under the chairmanship of H. S. Arkell, Dominion President of the C.S.T.A.

Professor A. M. Shaw, Dean of the Faculty of Agriculture, University of Saskatchewan, presented a masterly analysis of the agricultural situation in western Canada and was given an ovation at the close of his address. Dean Shaw has been requested to prepare this material for publication and it is expected that it will appear in a later number of *Scientific Agriculture.*

Short speeches were also made by Dr. G. I. Christie, President of the Ontario Agricultural College; Dean H. Barton of Macdonald College; M J. H. Lavoie, Chief of the Horticultural Service, Quebec Department of Agriculture; Dr. W. T. Macoun, Dominion Horticulturist and past President of the C.S.T.A.; Dr. W. V. Longley, Director of Extension, Nova Scotia Department of Agriculture, and W. A. Weir, Secretary-Treasurer of the Ontario Honey Producers.

The General Secretary of the C.S.T.A., H. L. Trueman, was given a warm reception on his appearance after five months of confinement to his home. Mr. Trueman expects to return to part time office work shortly.

C.S.T.A. DIRECTORS MEETING

The annual fall meeting of the Directors of the C.S.T.A. was held in the club room of the Royal York Hotel on Friday afternoon, November 20th. Mr. H. S. Arkell, Dominion President, presided and the General Secretary presented an extensive agenda of business items.

Among the most important matters discussed was the place of meeting in 1932. It was decided to postpone the Saskatoon Convention until 1933 in order to join with the World's Grain Exhibition and Conference in that year. The meeting point for 1932 was left to the Dominion Executive to decide in cooperation with the executive of the Canadian Seed Growers' Association and organizations affiliated with the C.S.T.A.

In accordance with the wishes of the 1931 convention and the best judgment of the Directors it was decided to amalgamate the Committee on Agricultural Policies with the Committee on Educational Policies and to supersede the Committee on Economics and Marketing by reports from the Canadian Society of Agricultural Economics. Further information will be sent direct to the members of these committees.

The policies of the Society were discussed at considerable length, and to clarify matters it was decided to name a committee to investigate how the C.S.T.A. can best discharge its responsibility to farmers and the general public, and what steps, if any, may be taken in advance of the general policies followed by the Society up to the present time. This committee will be headed by Mr. H. S. Arkell.

NOTES AND NEWS

D. A. McCannel (Alberta '24) has changed his address to 128 Ninth Avenue N.W., Edmonton, Alta.

M. H. Hudon (Laval '25) was married on November 17th to Miss Florence L. Rivest of Ottawa and has taken up residence at the Commodore Apartments, Rideau Street, Ottawa.

J. Y. Kellough (Toronto '25) has changed his address to 25 King Street West, Toronto 2.

Logan T. Wilson (Saskatchewan '24) received his Ph. D. degree at the University of Wisconsin last June and is now in charge of nutritional research at the Walker-Gordon Laboratories, Plainsboro, N.J.

E. R. Bewell (Manitoba '14) has changed his address to 1121 Stride Avenue, New Westminister, B.C., and has accepted a position as Fieldman for the B. C. Egg and Poultry Pool.

R. E. English (Alberta '28) is doing graduate work in the Department of Political Science, University of Toronto. His address is 301 Davenport Road, Toronto.

J. Sydney Dash (McGill '13), Director of Agriculture in Georgetown, British Guiana, has returned to duty after spending the summer in Canada.

H. S. French (Toronto '16) District Agriculturist, has moved his headquarters to Prince George, B.C.

C. C. Kelley (Alberta '25) has changed his address to Department of Agriculture, Kelowna, B.C.

D. F. Patterson (McGill '27) is doing graduate work at the University of Western Ontario, London, Ont., in applied biology. His permanent address is Vineland Station, Ont.

SELECTED LIST OF ACCESSIONS TO THE LIBRARY OF THE DOMINION DEPARTMENT OF AGRICULTURE.

(Members of the C.S.T.A. may borrow these postfree by addressing a request to the Library, Department of Agriculture, Ottawa)

American bison society. Report. 1927-30. New York, 1931. 69p. il.

American society for testing materials. Symposium on developments in automotive materials. Philadelphia, Pa. 1930. 186 p. il.

American statistical association. Journal. Vol. 26, 1931. New York.

Association internationale des selectionneurs de plantes. Bulletin. Versailles, France.

Atanasoff, D. & Petroff, D. List of plant diseases in Bulgaria. Sofia, 1930. 102 p.

Atanasoff, D. Mosaic disease of flower bulb plants. Sofia, 1928. (reprint from Bul. de la Soc. bot. de Bulgarie. 1928. pp. 51-60.—in English).

Baker, O. E. A graphic summary of American agriculture based largely on the census. Washington, D.C. 1931. 228 p. (U.S.D.A. Miscellaneous publication no. 105).

Barney, C. D. & co. The tobacco industry annual review, 1931. New York, 1931. 29 p.

Brookens, P. F. The competitive position of the dairy industry of New Zealand. Washington, D.C. 1931. 52 p. mimeo. (At head of title: U. S. Bureau of agricultural economics).

Canada. National development bureau. Leeds and Grenville counties, Ontario, with special reference to its resources and industries. Ottawa, 1931. 87 p. mimeo. maps, diagrams.

Canada. Dominion bureau of statistics. Alphabetical list of products manufactured in Canada, 1929. Ottawa, 1931. 33 p. mimeo.

Canada. Dominion bureau of statistics. The trade of Canada with Japan and China. Ottawa, 1931. 17 p. mimeo.

Canadian seed growers' association. Annual report, 1930-31. Ottawa, 1931. 129 p. il.

Casey, M. comp. Catalogue des brochures aux archives publiques du Canada, 1493-1877 avec index. Ottawa, 1931. 553 p.

Cattell, J. McKeen and Cattell, Jaques. editors. American men of science; a biographical directory. New York, Science press 1927. 1132 p.

Chamber of commerce of the United States. Federal and state land policies affecting agriculture. Washington, D.C. 1931. 36 p.

Chinese eastern railway. Land department. Experimental results of the investigation of storage conditions and artificial drying of soya bean. Harbin, China, 1931. 79 p. (Illustrations of interest. Text is in Russian).

Collins, C. W. Rural banking reform. New York, Macmillan co. 1931. 187 p.

Cooper, H. L. Trade with Russia. Washington, D.C. American-Russian chamber of commerce, 1931. 11 p.

Copland, D. P. editor. An economic survey of Australia. Philadelphia 1931. 280 p. (Annals of the American academy of political and social science. Vol. 158, Nov. 1931).

Dairy shorthorn association. Year book, Vol. 13, 1930. London, 1931. 551 p.

Dykes, W. R. Notes on tulip species. London, Herbert Jenkins ltd. 1930. 108 p. colored plates. Bibl. pp. 9-10.

Gt. Brit. Ministry of agriculture & fisheries. Fourth progress report of the foot-and-mouth disease research committee. London, 1931. 375 p. Bibl. pp. 360-375.

Hayward, Phillips A. Wood, lumber and timbers. New York, Chandler cyclopedia, 1930. 521 p. illus.

Hegner, Robert, and Andrews, Juston. Problems and methods of research in protozoology. New York, Macmillan co. 1930. 532 p. il. Bibl. pp. 475-520.

Hiller, E. T. and others. Rural community types. Urbana, Ill. 1928. 134 p. (University of Illinois. Studies in the social sciences. Vol. 16 no. 4).

Imperial bureau of plant genetics. Rice breeding bibliography. Cambridge (1931) 24 p. mimeo.

Institut international d'agriculture. Aspects et problèmes de l'agriculture exposés par les Ministres de l'agriculture encharge de quarante pays. Rome, 1930. 166 p.

Institution of chemical engineers. Transactions. Vol. 8, 1930. London, 1930. 232 p.